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VEGETATIVE MORPHOLOGY AND ANATOMY OF THE SALT MARSH RUSH, *JUNCUS ROEMERIANUS*

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ABSTRACT The extensive rhizome development found in *Juncus roemerianus* makes this species unique among rushes and is a biological feature responsible, in part, for its domination of large tracts of salt marsh. Branching in certain mature plants is distinctly sympodial, while in most it is obscured by precocious development of the continuation bud and appears to be monopodial. Each vegetative unit is composed of a scaly rhizome which grows to varying lengths and then abruptly turns up at the end to become an erect shoot. A continuation rhizome consistently arises from an axillary bud in a ventral scale leaf. Transitional leaves (large scale leaves) accompany development of the erect shoot. Rhizome scales, transitional and foliage leaves are distichously arranged and in the same vertical plane. The culm forms through an elongation of an internode of an erect shoot. Other rhizomes may also arise from buds in the axils of the transitional and foliage leaves. From one to seven terete leaves with a bifacial sheath are produced from the apical meristem of the erect stem. Fibrous roots occur laterally on erect shoots. Non-fibrous roots occur on the ventral surface to the rhizomes. The internal rhizome and root anatomy resembles that reported for most other species of *Juncus* while the leaf anatomy is very similar to that of *Juncus maritimus* and *Juncus acutus*.

INTRODUCTION

Juncus roemerianus Scheele is a rush dominating major tracts of salt marsh on the Atlantic and Gulf coasts of the United States (Eleuterius, manuscript in preparation). The most successful herbaceous plants occurring in these maritime marshes are those which are perennial and reproduce vegetatively by vigorous rhizome growth, thus leading to the formation of dense stands. Once established, these species do not generally rely on the sexual cycle for maintenance of the closed stand. The importance of understanding the structure of herbaceous species has become apparent in the study of crop plants where solution of practical problems arises (Hayward 1938; Bonnett 1935, 1940). Only through fundamental knowledge of the pattern of growth, entailing basic morphology and anatomy, can proper analysis of variation in species be attained. Structural studies of salt marsh species have similar importance since successful management of estuaries will ultimately require familiarity with each wild species to the same extent and detail now available for cultivated crop plants.

Although there are several reports (Adamson 1925; Cutler 1969; Stace 1970) on the internal anatomy of various *Juncus* species, comparable studies on the vegetative morphology are lacking. Some general morphological aspects of certain rushes are described by Buchenau (1906) and Richards and Clapham (1941). Anderson (1974) in a general anatomical survey of seven salt marsh plants in North Carolina also included descriptions of some anatomical features of *J. roemerianus*. The present study describes in detail the vegetative morphology, pattern of growth, and anatomy of mature plants of *J. roemerianus* as found in Mississippi.

METHODS AND MATERIALS

Plant portions consisting of rhizomes (subterranean segments 30 to 60 cm in length) bearing erect shoots and roots were dug out for morphological study. Plant material was taken from more than 20 different habitats. These habitats varied in several ways: leaves of *J. roemerianus* in some places were abundant, sparse, tall, short, in pure stands and associated with other vascular plants. Plants were also examined from low, intermediate and hypersaline marshes, as were plants colonizing new terrain, where they grew without competition. Plant material for anatomical work was fixed in a formalin, proprionic acid and ethyl alcohol solution (FPA), processed using a tertiary butyl alcohol series and embedded in the usual manner. Sections were cut 10–15 microns on a rotary microtome, affixed to slides using Haupt's adhesive and stained with safranin and fast green using standard procedures outlined by Johansen (1940) and Sass (1958).

VEGETATIVE MORPHOLOGY

General

A single mature plant of *J. roemerianus* is difficult or impossible to discern by cursory examination in a typical stand. Rhizomes may connect hundreds of erect shoots of a single plant in a relatively small surface area of marsh. The continuous proliferation and subsequent senescence of rhizomes account for the vegetative spread and maintenance of the mature stand (Eleuterius 1975). Long, interconnected rhizomes bearing erect shoots and roots represent a portion of a single clone and serve to illustrate the typical mature plant. The vegetative axes of the mature plant are dimorphic with a clear distinction between horizontal and erect shoots (Figure 1A), but the sequence of events typical of sympodial branching is often obscured by the vigorous growth associated with the horizontal axis.

The Rhizome

Rhizomes possess tightly overlapping leaf-like scales or

cataphylls which arise ventrally and dorsally. The plane of distichy is vertical. The rhizome apex does not grow indefinitely but eventually becomes an indeterminate erect, leafy shoot. Young rhizome portions are generally larger in diameter than older parts, which become somewhat constricted with age. Rhizomes range in diameter from 2 to 18 mm, the average ones being about 9 mm. The internode length may vary from a millimeter or less to over a centimeter. The rhizome bud is formed periodically in the axil of a scale leaf which arises on the lower surface of the rhizome (Figure 1B–E). The division of the rhizome apex is almost dichotomous with the resulting dorsal meristem being only slightly larger than the ventral. The dorsal and ventral meristems are destined to form the erect shoot and new rhizome, respectively. In most instances the terminal rhizome bud develops precociously and continues to grow at such a rapid rate that the sympodial branching pattern is obscured to the extent that it may be erroneously interpreted as monopodial. The precocious growth of the rhizome bud displaces the terminal bud of the previous unit, which becomes an erect, leafy shoot. This displacement occurs in such a way that the leafy shoot appears to be inserted at the middle or, more often, toward the distal end of the rhizome internode. Occasionally, a rhizome may arise from a bud formed on the dorsal side of the rhizome apex which grows in a direction opposite the terminal rhizome when eviction of the leafy shoot occurs. The apex of the dorsal rhizome becomes oriented in the opposite direction from that arising from the ventral bud. As many as three rhizomes may arise from a single erect shoot. These new rhizomes may occur in the same or opposite directions. Most new rhizomes arise in leaf axils on the side of the erect shoot synonymous to the ventral surface of the rhizome (Figure 1F–G). Deflection of apexes by obstructions in the substratum causes many planes of growth or centrifugal spread of the plant. Consequently, all new rhizome production is in one plane. Axillary buds of the erect shoot, synonymous to the dorsal surface of the rhizome, give rise to new rhizomes which reinvade terrain previously occupied by the plant (Figure 2A and B).

The number of nodes or internodes between erect shoots is variable. In some localities the number may vary from 10 to 18, in others 6 to 12, or 1 to 5. The number varies within the same clone. However, most material examined ranged from 8 to 14 and averaged about 12 nodes between erect shoots. In seedlings only one node may exist between erect shoots (Eleuterius 1975). The distance between erect shoots may be minute to 5.5 centimeters or more, the average being about 2.5 centimeters (Figure 2C–E).

The Erect Shoot

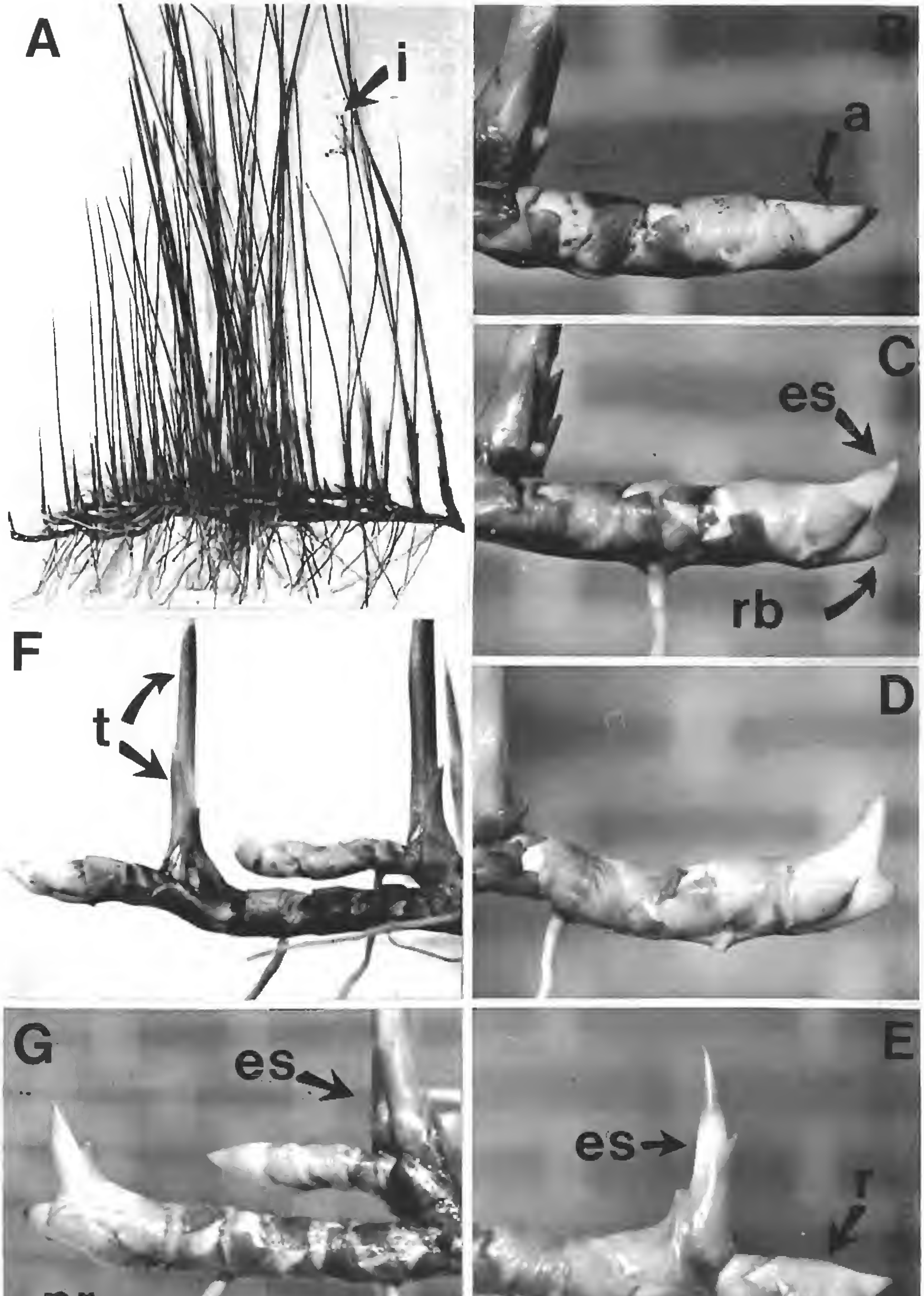
The mature erect shoot may vary from one to several centimeters in length and consists of a series of nodes and compressed internodes. The growth of the erect shoot is determinate, culminating in the production of terete leaves or a culm. Apparently as the erect shoot develops, the scale leaves become longer and tougher in texture as each successive node is produced. These may be conveniently referred to as transitional leaves, contrasting with the scale leaves of the rhizome and terete foliage leaves. There are generally three to five present on each erect shoot. The arrangement of transitional and foliage leaves is distichous.

A culm is apparently not produced on every erect shoot, some of which then remain leafy throughout their existence. The culm is an elongated internode of the erect shoot, which elevates meristematic tissue destined to be the inflorescence. A red band circumscribes the floral meristem (node) of the culm and separates the internode region from the bract which subtends the inflorescence. Culm production terminates the life of the erect shoot. However, the rhizome units supporting the erect shoot may remain alive. The culm appears externally much like a leaf; however, it is weakly developed and is broken more easily than the leaf.

The Foliage Leaf

All foliage leaves are cylindrical or unifacial above the sheath with the abaxial surface to the exterior. The lower portion or sheath of the foliage leaves is bifacial with free margins through which new leaves emerge. All sheaths are rolled and the leaf margins form a slit through which subsequent leaves protrude as they are produced by the apical meristem of the erect shoot. The position of the slit alternates with each successive leaf produced. Leaf production is two-ranked or distichous. Thus, the second leaf generally emerges from a slit on the abaxial surface of the first leaf. As many as seven leaves may arise sequentially from the relatively short erect shoot. The upper portion of terete leaves are stiff and pointed at the end, and may range in diameter from a few millimeters to three-quarters of a centimeter; the average is about 3 millimeters. Mature leaves range in length from 30 to 223 cm, depending on the habitat. Over most of the local population they average about 100 cm.

Figure 1. Vegetative morphology of *Juncus roemerianus*. 1A. A general view of a portion of a mature plant. All units of the sympodium shown are connected and may be traced back to the parental unit on the right. Note that the orientation of most new vegetative units occurs in the same direction with respect to the parental unit (i = inflorescence). 1B. Rhizome apex (a) after forming in this case after five nodes and internodes were produced. 1C. Erect shoot (es) forming by eviction and precocious development of a terminal rhizome bud (rb). The rhizome bud forms in the axil of a scale leaf on the ventral surface of the rhizome. The plane of distichy of the scale leaves is vertical. 1D. Subsequent development of an erect shoot and rhizome buds as shown in preceding view at C. 1E. Later development of erect shoot (es) and rhizome (r). Note development of the two axes are about equal. 1F. General view of rhizomes arising from erect shoots. Note erect shoot (to right) gave rise to two rhizomes. Transitional leaves (t) (scale leaves) accompany early development of erect shoot. 1G. Erect shoot developing after seven nodes and internodes are formed by rhizome apex. Non-branching anchoring roots (nr) arise from nodes on the ventral surface of rhizome.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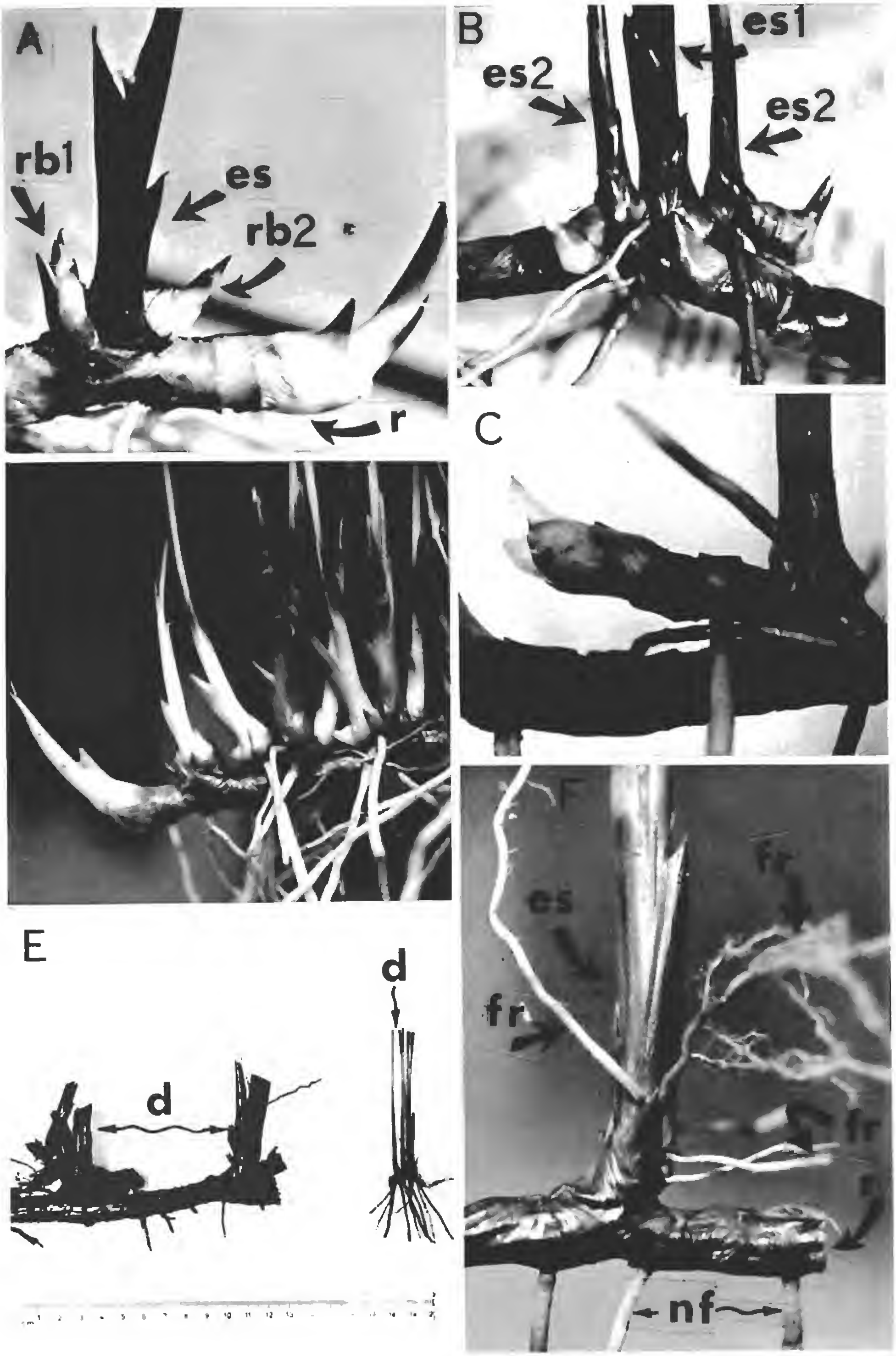
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The Roots

There are two types of roots found in *J. roemerianus.* One type branches frequently, is relatively small in diameter and somewhat stiff. The other type generally does not branch or does so infrequently. These roots are relatively large, succulent, deeply penetrating and consistently arise from the lower surface of the rhizome near the apex. The development of fibrous roots is somewhat delayed and restricted to the lateral surface (perpendicular to the plane of distichy) of the mature erect shoot (Figure 2-F).

VEGETATIVE ANATOMY

The Leaf

The mature leaf blade is symmetrical in cross section (Figure 3A). There is a single-layered epidermis with the outer cell wall thickened and heavily cutinized. Stomata are not recessed. The stomatal cavity or substomatal chamber occurs in the palisade at a depth of one to several cells. Procumbent protective cells line the substomatal cavity (Figure 3B and C).

The chlorenchyma is composed of six to seven layers of elongated palisade cells with slightly swollen, pointed ends. The cells, more or less perpendicular to the leaf surface, appear to radiate from sclerenchyma girders or strands which occur next to the epidermis in triangular or irregular patches in cross section. These strands are often close together, separated by the width of the stoma only (Figure 3C–F). Other strands of sclerenchyma, more or less rounded or oval in outline, are scattered in the central ground tissue especially toward the solid parenchyma leaf center where each is surrounded by a parenchyma sheath. Both inner sclerenchyma and outer parenchyma bundle sheaths surround the vascular bundles.

The vascular bundles generally occur in two or three rings in the cylindrical leaves. Large vascular bundles with two medium-sized metaxylem vessels on either flank occur in the leaf center. The smaller bundles occur outermost and may be arranged in two or more rings, some free in the central ground tissue of the culm. However, most of the vascular bundles are concentrated near the periphery of the leaf. The phloem of the vascular bundles is external to the xylem and the arrangement of the vascular tissue within the leaf resembles that of an atactostele. The phloem is frequently surrounded on the outside by sclerenchyma or thick-walled parenchyma cells. Fibers are often found in the phloem. A series of branching parenchyma cells radiate from the sclerenchyma girders to the vascular bundles. These cells are stellate, a highly specialized polyhedral cell type, and form transverse diaphragms or septa within the leaf (Figure 3D).

The Culm

The flowering stem or culm is weakly developed and easily broken. Chlorenchyma occurs beneath the single layer epidermis. It is composed of irregular or rounded cells, two to three cells in thickness, and a few strands of sclerenchyma. These sclerenchyma girders are much smaller than those found in the leaf. The culm center is composed of continuous parenchyma. A series of radiating diaphragms of stellate, lobed cells or branching parenchyma are also found in the culm. The vascular bundles are fewer in number but larger in size in comparison to those of the leaf (Figure 4A and B). However, the orientation of the phloem is the same as for the leaf, being external to the xylem. The stomata are not sunken. Protective cells are found lining the substomatal cavity. The isodametric cells of the chlorenchyma are loosely arranged, which allows for the presence of air cavities (Figure 4C and D).

The Rhizome

The abaxial side of the rhizome scale or cataphylls contains an epidermis covered by a thick layer of cutin. The epidermis of the scale is one cell in thickness, but the cells are very large. A parenchyma layer from several to 20 cells thick may be found between the upper and lower epidermis. The rhizome has an epidermis of one cell in thickness which often contains lignin. Under the epidermis occurs a many-layered hypodermis which generally varies in thickness along a single rhizome or between rhizomes of different habitats. The outer cell layers of the hypodermis are often lignified and filled with an unidentified material. Lignification accompanied by apparent suberization is pronounced in older rhizome portions. Under the hypodermis is a thick layer of loosely arranged parenchyma, considered to be cortex. The innermost layer of the cortex is a single endodermoid layer. In older portions of the rhizome, endodermoid cells have thickened inner walls. A pericycle, a layer of parenchyma

Figure 2. Vegetative morphology of *Juncus roemerianus.* 2A. Erect shoot and associated rhizomes and rhizome buds. Rhizome (r) was formed simultaneously with erect shoot (es). Rhizome bud (rb1) arises dorsally on the rhizome slightly behind the erect shoot (es). Rhizome bud (rb2) arises from the erect shoot. Note that the buds at rb1 and rb2 are forming erect shoots immediately after being formed. 2B. Erect shoot (es1) and associated erect shoots (es2) which arose from buds as described at A. 2C. Secondary rhizome developing erect shoot and rhizome bud which forms a further unit of the sympodium. 2D. Proliferation of erect shoots on colonizing plants growing without competition. Note that rhizome buds form erect shoots immediately. This example shows that elongated rhizomes between erect shoots are not formed in all instances. 2E. Distance (d) between erect shoots of mature plants varies between habitats. The segment of rhizome on the left has about 14 nodes and internodes separating erect shoots. This plant grew under conditions which apparently favored vegetative reproduction. The leaves were over 7 feet in length. The segment on the right has only a few nodes and compressed internodes between erect shoots. This plant grew under hypersaline conditions. 2F. Location of fibrous roots (fr) on erect shoot (es). These roots generally arise perpendicular to the plane of distichy on the lateral side of the erect shoot. Nonfibrous (nf) or anchoring roots arise from the ventral surface of the rhizome.

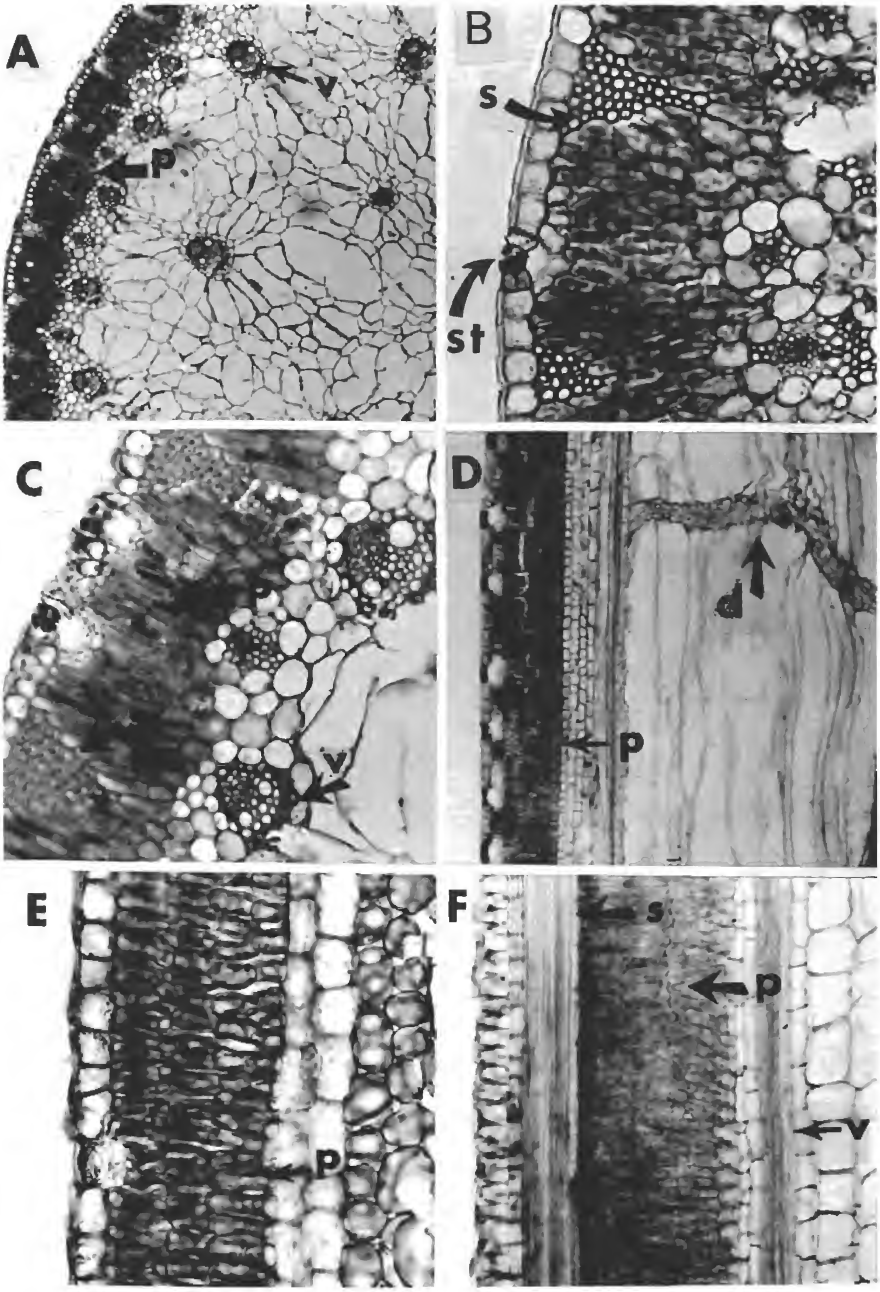


Figure 3. Anatomy of the leaf of *Juncus roemerianus*. 3A. Transection of leaf. Note the thick layer of palisade cells (p) forming chlorenchyma and vascular bundles (v). 3B. Leaf cross section showing sclerenchyma girders appressed against the epidermis and stoma (st) Note the procumbent protective cells lining the substomatal chamber. 3C Transection of leaf showing general arrangement of palisade cells (p) between sclerenchyma girders (s) and stomata (st). Vascular bundle (v) gives general view and shows phloem oriented external to the xylem. 3D. Longitudinal section of leaf showing a series of stomata on the extreme left underlaid by palisade cells (p). A diaphragm (d) or septum of stellate cells or branching parenchyma (polyhedrals). 3E and F. Longitudinal sections showing the regular arrangement of palisade cells (p), sclerenchyma girder (s) and vascular bundle (v).

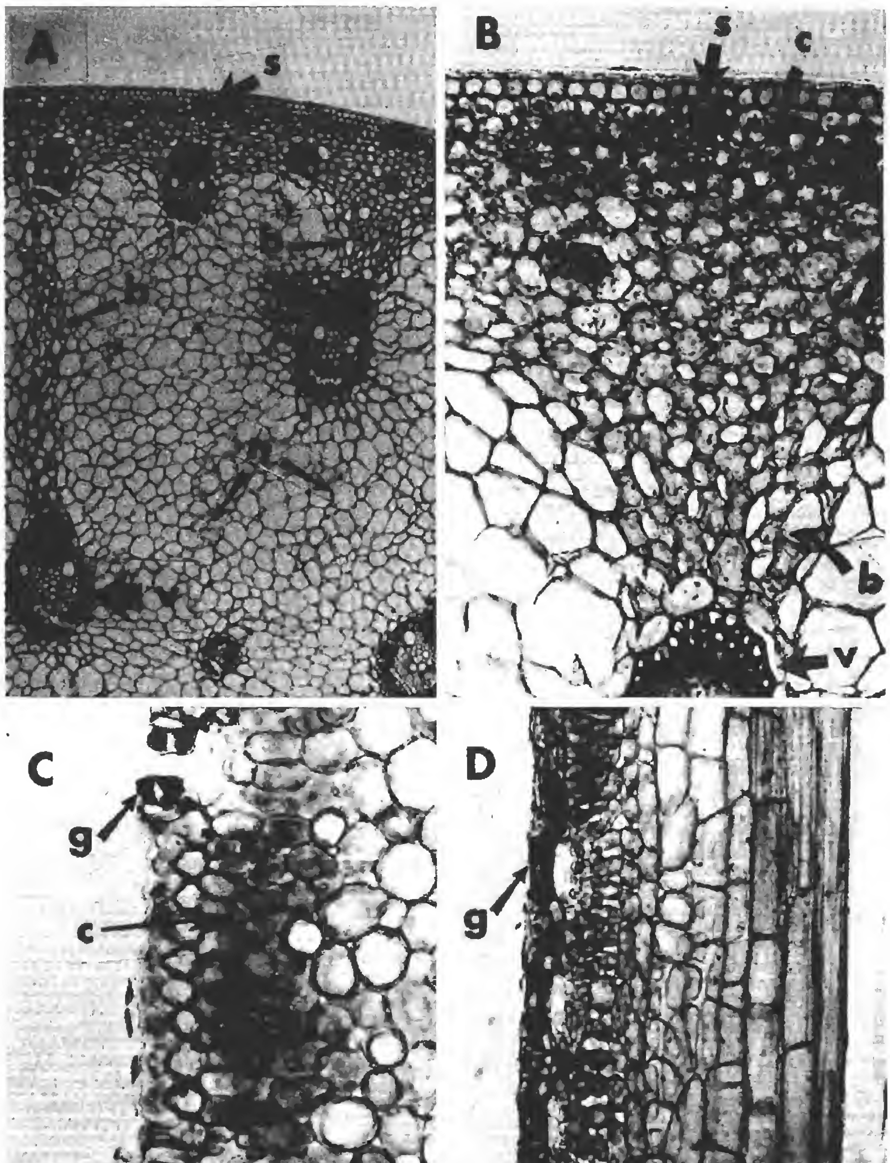


Figure 4. Anatomy of the culm of *Juncus roemerianus*. Transection of culm. Note arrangement of vascular bundles (v), diaphragms of stellate cells or branching parenchyma (b) and non-branching parenchyma (n). Sclerenchyma girders (s) are very small in comparison to those of the leaf. 4B. Close view of leaf in cross section showing sclerenchyma (s) and absence of palisade cells. Irregular or rounded cells form a thin layer of chlorenchyma (c). Note stellate cells (b) of diaphragm and extension to vascular bundles (v). 4C. Greater magnification of leaf cross section showing stomata with guard cells (g) and thin layer of chlorenchyma (c). 4D. Longitudinal section of leaf showing orientation of stomata and guard cells (g). Note loose arrangement of chlorenchyma.

tissue two to five cells in thickness, occurs immediately inside the endodermal layer. The center of the rhizome contains numerous amphivasal vascular bundles surrounded by parenchyma cells. Generally more vascular bundles are found near the outer portion of the stele than in the center. The smaller vascular bundles, often tortuously fusing or dividing, occur immediately to the inside of the pericycle. The central ground tissue is parenchyma (Figure 5A–C).

The Roots

Although there are two types of roots, based on general morphology, no major anatomical differences were noted in comparing the two types. The roots have an epidermal layer one cell in thickness. The cortex is composed of radiating plates of cells separated by air spaces or lacunae. The outer part of this cortex is composed of a layer of hexagonal cells, three to nine cells in thickness. The inner part of the cortex is composed of a layer of rounded, thin-walled cells, which becomes thicker in older roots. This layer is three to eight cells thick. The endodermis is one cell in thickness, with very thick inner and anticlinal walls and thin outer walls. A pericycle, a layer one to three cells in thickness, occurs immediately within the endodermis. Phloem persists in mature roots as inconspicuous patches pressed against the pericycle. The entire center of the root appears to be composed of xylem. However, small, thick-walled cells which may be sclerified parenchyma, compose the central portion of the xylem and from 1 to 24 large vessels arranged in a ring occur in the outer portion of the stele where they are sometimes accompanied by a central metaxylem vessel in larger roots (Figure 5D and E). Individual metaxylem vessels may be surrounded on the outside by one layer of flattened tracheids (Figure 5F–G).

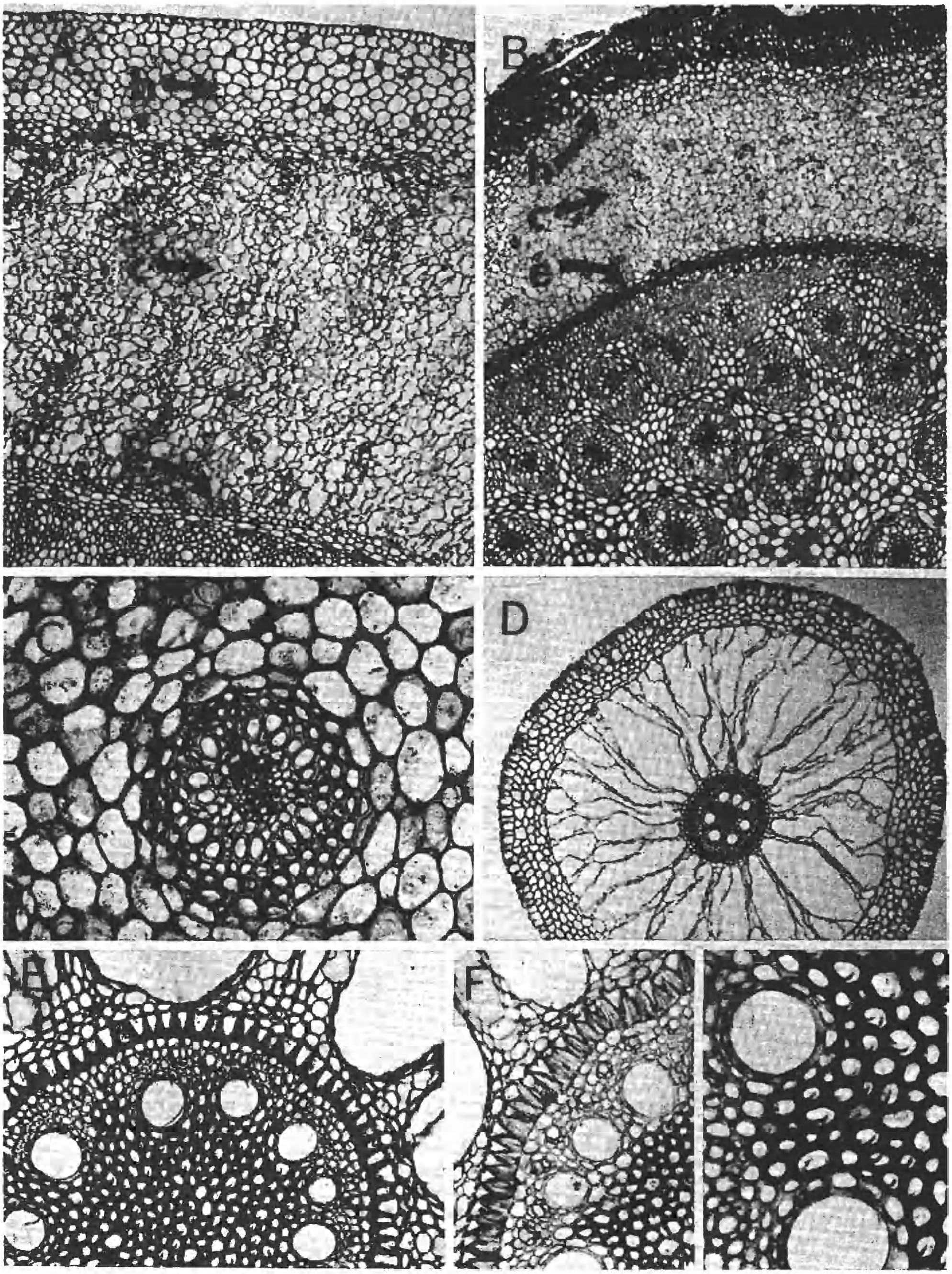
DISCUSSION

In an earlier account it was suggested that *J. roemerianus* possesses monopodial branching (Eleuterius 1975). This was based on early stages of development in mature rhizome apices which showed where the meristem divided equally or nearly so with the resulting dorsal meristem often slightly larger than the ventral. The lower meristem gives rise to the dominant axis, the rhizome. In most cases the horizontal stem clearly exceeds the development of the erect stem. This prevailing condition suggested that two shoots had been initiated simultaneously, the horizontal shoot or rhizome being indeterminate. The branching is thus monopodial. Subsequently, a more detailed investigation showed that the earlier supposition was incorrect and that sympodial branching in most mature plants of *J. roemerianus* involved precocious rhizome bud formation at the rhizome apex. This precocious bud formation is followed by vigorous rhizome growth, thus obscuring the clear-cut example of sympodial branching exhibited by immature and certain mature plants. The elongated rhizomes formed between the erect stems are peculiar and unique since in most species of *Juncus* where branching is distinctly sympodial the rhizome segment between erect shoots is rather short, resulting in a clumped habit. This is an important vegetative characteristic which accounts, in part, for the domination of *J. roemerianus* over large areas of salt marsh.

Sympodial branching implies that the plant is composed of units which are determinate and that further growth continues from axillary buds. In *J. roemerianus*, buds consistently arise in the axils of scale leaves on the ventral surface of the rhizome and frequently in the axils of transitional and foliage leaves on the erect shoot. Richards and Clapham (1941) state that the continuation bud consistently arises in the axil of the second scale leaf of *Juncus inflexus*. Anderson (1974) states that it occurs in the ninth scale leaf of *J. roemerianus*. However, I find the ventral scale leaf axil, in which the continuation bud occurs, to be highly variable. Sometimes it occurs immediately at the first node (where one node separates the erect shoots), while in other material the bud may be found in the axil of the eighteenth scale leaf (18 nodes separating the erect shoots). Thus, the formation of erect shoots and rhizome buds apparently does not occur after any fixed number of nodes. The number of rhizome nodes between erect shoots varies among plants from different localities and habitats of *J. roemerianus*.

In some populations of *J. roemerianus* rhizome growth is suppressed but the leaves are very long. In other areas the leaves may be relatively short, but rhizome growth is extensive. Various combinations of growth patterns exist in different habitats. In some areas of relatively low salinity, plants are often very robust with leaves over 7 feet in length, whereas, in hypersaline areas the plants are dwarfed (less than 1 foot). Whether this variation in the size of these plants is a response to environmental factors or due to genetic control remains unclear. However, data from reciprocal transplant experiments suggest that ecotypic adaptation may exist within *J. roemerianus*. Reduced plant size and increased vascularization of internal tissues is characteristic of plants which grow under saline conditions. However, the internal anatomy of various plant structures remains relatively constant. In dwarf plants the internal

Figure 5. Anatomy of the rhizome and roots of *Juncus roemerianus*. Transection of young rhizome showing arrangement and general appearance of tissues. The epidermis is a single layer of cells. The hypodermis (h), cortex (c) and endodermoid layer (e) are shown. The stele is composed of scattered amphivasal bundles. 5B. Transection of older rhizome showing well developed tissues. Note the lignified hypodermal cells (h) which may contain suberin. The cortex (c) and endodermoid layer (e) are well developed. The amphivasal bundles are well defined and are tightly appressed against the pericycle. 5C. An individual amphivasal bundle of rhizome stele. 5D. A cross section of a root. Note the large lacunae of the inner cortex, thick outer cortex and the relatively small vascular stele. 5E. Greater magnification of cross section showing detail of endodermis and vascular stele. Note the thick inner and anticlinal walls and thin outer walls of the cells of the endodermis. The metaxylem vessels are arranged in an outer ring. 5F. Another section of a root showing the endodermis with cell walls thicker than shown in E. This thickening appears to occur with age. 5G. Metaxylem vessel surrounded by flattened tracheids.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tissues are correspondingly reduced with an obvious reduction in the amount of parenchyma which occurs in all plant organs. The amount of parenchyma is partially restored in new organs of dwarf transplants when they are taken from hypersaline marshes and grown under low salinity.

The occurrence of stellate cells in the pith of the cosmopolitan *Juncus effusus* has been described in detail by Maas Geesteranus (1941). In *J. roemerianus, Juncus maritimus* Lam. and *Juncus acutus* L. these stellate cells form diaphragms and are regarded as a secondary development in the more advanced species (Buchenau 1906). Diaphragms have been found in other water plants (Kaul 1971, 1973, 1974) associated with air chambers which provide internal ventilation. These diaphragms probably give strength without rigidity (Snow 1914; Williams and Barber 1961).

Several morphological and anatomical features are apparently related to water regulation. These include the presence of lignin and possible suberin in the outer layer of the hypodermis and cortex of the rhizome and roots, the well-developed endodermis of the roots and endodermoid layer of the rhizomes, the heavy cutinization of the rhizomes, scales and foliage leaves, and the fibrous leaves. Clements (1907) stated that in grasses and sedges the presence of large amounts of sclerenchyma in the leaves renders water loss difficult.

Internal anatomy has much use in taxonomic work. The presence of pith in the leaf was the characteristic used by Buchenau (1906) in defining *Juncus* subgenus *Thalassi*. Raunkiaer (1895) placed *J. maritimus* in a separate category because the vascular bundles of the leaf and culm are found throughout the culm and leaf center. Adamson (1925) and Cutler (1969) showed that the leaf anatomy of *J. maritimus* and *J. acutus* are essentially the same. Anatomically *J. roemerianus* resembles these two species of *Juncus* which have solid piths with vascular bundles. The chief anatomical differences which exist between *J. maritimus, J. acutus* and *J. roemerianus* are found in transverse sections of the leaf.

The detailed morphological and anatomical characteristics of *J. roemerianus* described in this paper may have taxonomic value in diagnostic work, especially where hybrids are concerned or suspected (Stace 1970; Eleuterius 1975). However, no differences in vegetative anatomy were noted within *J. roemerianus* when plants which produce perfect and pistillate flowers were compared (Eleuterius and McDaniel 1974).

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SHRIMP POPULATION DENSITIES WITHIN MOBILE BAY*

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ABSTRACT Brown shrimp and white shrimp populations available to the shrimp trawl in Mobile Bay were estimated on a monthly basis by two methods: one using existing commercial statistics and the other using experimental trawling. These methods produced similar estimates for brown shrimp whose peak standing crop in Mobile Bay occurred in June–July and was estimated at 200,000–300,000 pounds. Commercial landings peaked in July at about 342,000 pounds and were higher than the standing crop, indicating an extremely fast growth rate.

White shrimp data were variable, with commercial statistics indicating a crop in Mobile Bay of about 100,000 pounds from September to November and with experimental trawl data indicating a peak of 267,000 pounds in August. Average monthly harvests approached 100,000 pounds from August to October.

Abundance of pink shrimp was erratic and commercial shrimp statistics indicate variation from 475 pounds landed in 1956 to 34,000 pounds landed in 1957.

INTRODUCTION

The shrimp fishery is the most valuable fishery in the Gulf of Mexico. Its value and poundage have increased with the introduction of the gas engine, the otter trawl, and modern refrigeration; with the discovery of new fishery grounds; and most recently with the increase in fishing pressure. Despite the latest increase in fishing pressure, the total yield remained stable in the Gulf states until 1971. Variations since that time seem to have been related to rainfall and river flow (Gunter and McGraw 1973).

Gunter (1956) said that because of extremely fast growth rates of shrimp in warm months, no reasonable amount of fishing would reduce the total weight of the population during these months.

Loesch (1962) stated, "According to pioneer shrimpers, shrimping was much better in years gone by. Their observations may be faulty in that they may remember the exceptional catches but not their frequency. If there is a reduction in the number of shrimp in the bay now compared to twenty years ago a number of factors could be involved. Increased fishing pressure is not the only man-made difference in the bays. Agriculture, industry, and navigational improvements have wrought great changes, so former abundance is not a sure index to present potentialities."

Penaeus setiferus (Linnaeus) and *Penaeus aztecus* Ives are two species of commercial shrimp found more or less abundantly in all five Gulf states; *Penaeus duorarum* Burkenroad also is common in Florida and Texas and appears sporadically in the intervening states.

Loesch's dissertation (1962) was an attempt to add to the general knowledge of the shrimp during the time they live in brackish water. Loesch (1965) gave seasons they appeared in the bays and size distribution within different water depths, salinities, and areas. This paper attempts to estimate monthly populations of brown shrimp and white shrimp by using two different methods. One method uses commercial fisheries data, by determining both the ratio of area swept by commercial trawl to total area in Mobile Bay and the ratio of shrimp caught to total estimated population in Mobile Bay. The other method uses similar techniques but substitutes experimental trawl data for commercial trawl data.

*Part of Ph.D. Dissertation, Loesch (1962)

MATERIALS AND METHODS

The fishing mortality generated by a single operation, which may be considered as taking part of the whole stock, is equal to the fraction of the population caught. If the stock is evenly distributed and the gear effectively catches all the shrimp within a certain area (a), and if the total area inhabited by the stock equals A, then the fishing mortality is equal to a/A. The mortality generated by the whole fishery is then a^1/A, where a^1 is the sum of the areas covered by all the vessels of the whole fleet. The area covered would be the distance between the doors of the trawl times the total distance dragged.

There are two important sources of errors, acting in opposite directions. First, not all the shrimp in the area covered by the gear will be caught, resulting in an underestimation of available crop or population occupying area A. Second, the density of shrimp in the fished area will be greater than the average density, resulting in an overestimation of the available crop in area A. While the method is not suitable for an exact account of the population or available crop in area A, it may be useful in giving an indication of its magnitude. By estimating the population and knowing the commercial catch one can arrive at the fishing mortality.

Using a^1 as the sum of the area covered by all vessels in Mobile Bay during a given month, and A as the area of Mobile Bay (297 square nautical miles), then a^1/A is the number of times an area equal to A is swept. Using W_c as the

average pounds of shrimp caught commercially during each month with the fleet covering a^1, then the computed crop in pounds available to trawls at a given time during a given month would be $W_c/a^1/A$. A trawling speed of 3 knots and an average net spread of 60 feet were assumed in making these computations.

Another estimate may be obtained from experimental trawl data. A 23-foot trawl was dragged at 3 knots for 30 minutes at each of 12 bay stations (Figure 1). This covered about 0.068 square nautical miles, or about 1/4370th of Mobile Bay. Using w_c as equal to the pounds of shrimp caught with this gear, then the product $(4370 \times w_c)$ would be equal to the computed crop in pounds available to trawls during any given month. Thus, two estimates of available crop were made.

The average poundage of each species of shrimp caught commercially during each month and the average number of days fished during each month were computed from U.S. Fish and Wildlife Service statistics (1956–1960). During July, August, and September of these years a^1/A was greater than 1. This means that an area greater than the total area of Mobile Bay was swept by commercial gear during each of these months. Therefore, $W_c/a^1/A$, or the estimated shrimp available at a given time during the month, is less than the total shrimp caught during the month by the commercial fishery. For a more accurate picture, daily records would have been better, but such data were not available. However, an average for daily W_c figures would be about one-thirtieth of the monthly figures, and a daily average of area swept would be about one-thirtieth of a^1. Therefore, figures obtained on the estimated standing crop would be very similar to those obtained from monthly figures.

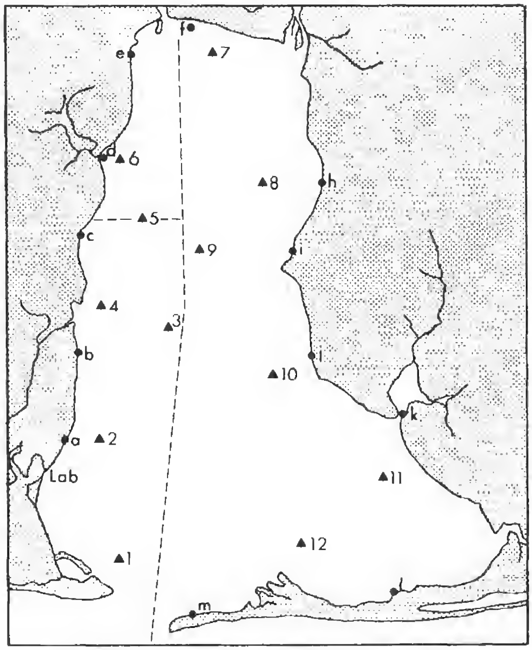
RESULTS AND DISCUSSION

Brown Shrimp

Data from experimental trawling for brown shrimp *P. aztecus* indicate that the amount of shrimp caught during July and August was greater than the estimated standing crop available to trawlers at any given time during these months (Table 1). During September the amount caught was about equal to the estimated standing crop available. The experimental data closely parallel data obtained from the commercial fishery, especially during the brown shrimp season which lasts to October. From October on, more white shrimp were caught.

Loesch (1962) shows that the length-frequency, means, and modes advanced only slightly from June to August and there often was a decrease in the modal length. Large numbers of small brown shrimp were available around the edges of the bay to replace those caught by trawl. With fast growth and an ample recruitment stock, it is possible for the monthly poundage of shrimp caught to exceed the pounds available at a given time.

A drag bar used during the sampling program covered a strip 2.5 feet (0.76 m) wide (Figure 2). The 10 nearshore stations constituted a sampling of 25 feet total shoreline since hauls were made perpendicular to shore. The shoreline



	Bay Stations		Inshore and nearshore stations
1	Beacon No. 4	a	Alabama Port
2	Alabama Port	b	Austins
3	Beacon No. 18	c	Bellefontaine
4	Fowl River	d	Dog River
5	Deer River	e	Brookley Field
6	Dog River	f	South of Causeway
7	Devil's Channel	g	North of Causeway
8	Daphne	h	Daphne
9	Dredge	i	Fairhope
10	Mullet Point	j	Mullet Point
11	Bon Secour	k	Weeks Bay
12	Little Point Clear	l	Pleasure Point
		m	Fort Morgan

Figure 1. Location of stations in Mobile Bay.

of the bay is about 425,000 feet, so the gear sampled about 1/17,000th of the shoreline area. If the areas sampled are representative, millions of very small young brown shrimp were always available around the periphery of the bay from April to September (billions during the peak season) to replace those removed by man and other predators.

The apparent two periods of recruitment in brown shrimp populations may not reflect spawning peaks but rather a combination of growth and survival peaks. Subrahmanyam's (1971) studies in Mississippi indicate that the commercial penaeids spawn during most of the year and that influx of larvae into the bays is related to factors other than spawning peaks. Peaks in recruitment may occur at times when competition is least—early in the season before the area becomes densely populated and again when the first "crop" that is able to survive moves out into the Gulf.

There was little change in mean size of young brown

TABLE 1.

Various trawl data of brown shrimp catch relationships in Mobile Bay, Alabama.

Month	g	a^1/A	W_c	$W_c/a^1/A$	$4370 \cdot w_c$	W_c/g
January	0	insuf	0	insuf	17,000	0
February	0.2	0.005	53	insuf	26,000	insuf
March	32.0	0.078	1,699	21,782	8,000	53
April	17.0	0.041	2,101	51,244	21,000	124
May	69.0	0.167	12,390	74,192	28,000	180
June	397.0	0.962	171,270	178,035	297,000	431
July	708.0	1.716	342,135	199,379	205,000	483
August	685.0	1.660	175,293	105,598	114,000	256
September	444.0	1.076	38,245	35,544	41,000	86
October	316.0	0.766	6,900	9,007	48,000	22
November	246.0	0.596	5,605	9,404	16,000	23
December	51.0	0.124	677	5,459	12,000	13

g = average number of 24-hour fishing days in Mobile Bay (1956–60)
a^1 = sum of areas swept by trawl of entire fleet in Mobile Bay (1956–60)
A = total area of Mobile Bay
a^1/A = number of times area equal to a^1 is swept by trawls in Mobile Bay (1956–60)
W_c = average pounds of shrimp caught commercially in Mobile Bay (1956–60)
$W_c/a^1/A$ = computed crop of shrimp in pounds available to trawls at a given time during a given month as estimated from swept areas (1956–60)
w_c = pounds of shrimp caught with 23-ft trawl dragged for 30 minutes at 12 bay stations (July 1953–Sept. 1955)
$4370 \cdot w_c$ = computed crop of shrimp in pounds available to trawls at a given time during a given month as estimated from experimental trawling (July 1953–Sept. 1955)
W_c/g = average pounds of shrimp tails caught per day commercial trawling (1956–60)

shrimp taken near shore. When the mean length remains constant, there apparently is continuous recruitment of young shrimp and migration of slightly larger shrimp off shore. The mean size varied from about 20 mm in April or March, when the young shrimp first appeared in the bay, to about 40 mm the first month after appearance. A possible reason for this increase is the absence of an accumulated population of larger shrimp to migrate off shore this first month. Thereafter, with the population buildup completed, the larger individuals left the shore area and the mean varied between 30 and 50 mm.

Only in June, July, and August were above-average numbers of brown shrimp taken by trawl (Table 2). There was a general decrease in May, a great increase in June, followed by a gradual decrease until September and an increase in October. This is essentially the same pattern reported by Gunter (1950) in Texas.

The following is a list of the stations (see Figure 1) in order of decreasing average numbers of brown shrimp taken per 30-minute trawl: Deer River (station 5), Beacon No. 4 (station 1), Fowl River (station 4), Alabama Port (station 2), Dredge (station 9), and Dog River (station 6). Of these six top producers all except the dredge station are located on the western side of Mobile Bay. The remaining stations, continuing in order of decreasing abundance, are as follows: Mullet Point (station 10), Little Point Clear (station 12), Bon Secour (station 11), Beacon No. 18 (station 3), Daphne (station 8), and Devil's Channel (station 7). Detailed figures are given in Table 2.

Deer River (station 5) had the largest number of shrimp primarily because of the larger winter catches there. The 32-foot water is somewhat warmer than that of the surrounding shallower area during the winter. The channel is oriented in an east-west direction, so shrimp attempting to leave the bay in a north-south direction would cross the channel. Although the water at Beacon No. 18 (station 3) is 35 feet deep, this channel runs north and south, so shrimp are able to continue their north to south movement within the deeper water of the channel and for this reason do not accumulate in the main ship channel in winter as much as they do in the Deer River channel.

White Shrimp

Using the same procedures outlined in the discussion on brown shrimp, tabulations of estimated standing crop using experimental trawl data and commercial catch data are given for white shrimp *P. setiferus* in Table 3.

The experimental data reveal that some larger shrimp came into the lower bay during the early part of the year, but they left and by June almost no white shrimp were in the bay (Loesch 1962). Commercial statistics corroborate this. In July, according to experimental data, there was a rapid buildup. Commercial data do not indicate a population until August. Young white shrimp prefer fresher water, and during July most of the shrimp were in upper Mobile Bay, which is closed to commercial shrimping during this season. Also during July the commercial fleet is concentrating on the larger brown shrimp because the new population of white shrimp is very small. In August the experimental data again indicated a much larger population of white shrimp than was indicated by the commercial data (Table 3).

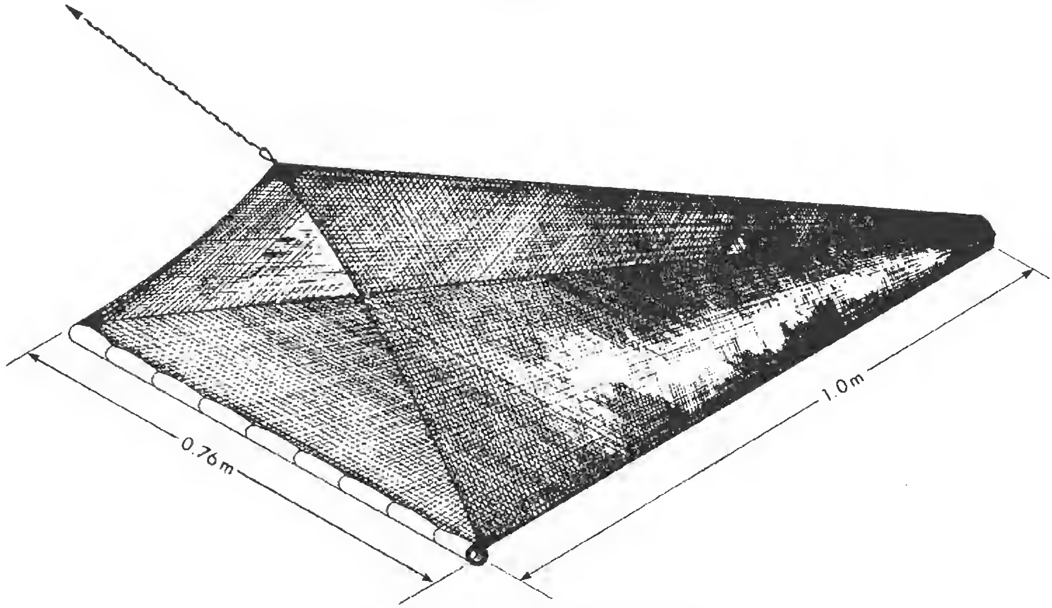


Figure 2. Drag bar for nearshore sampling.

TABLE 2.

Average number of shrimp taken each month at each bay station (July 1953–September 1955).

No.	Station	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Avg.
							P. aztecus							
7	Devil's Channel	0	0	0	0	0	22.0	2.7	1.5	5.5	20.0	0.5	1.5	4.0
6	Dog River	0.5	0	0	0.5	3.5	412.0	106.0	23.0	8.3	14.0	0	4.5	47.0
8	Daphne	0	0	0	0	18.0	132.0	69.0	0	1.3	2.5	1.0	0	19.0
5	Deer River	179.0	305.0	34.0	13.0	32.0	611.0	168.0	50.0	11.0	202.0	60.0	44.0	140.0
9	Dredge	3.5	0	0	0	4.0	249.0	206.0	22.0	1.5	32.0	10.0	0.5	73.0
4	Fowl River	0	1.0	0	0.5	24.0	802.0	134.0	74.0	6.0	2.5	3.5	14.0	89.0
10	Mullet Point	0	0.5	0	0.5	42.0	144.0	162.0	49.0	11.0	12.0	1.5	0	41.0
3	Beacon No. 18	3.5	4.0	0	0.5	54.0	33.0	210.0	48.0	7.5	4.0	3.0	5.5	38.0
11	Bon Secour	1.0	0	1.5	3.5	14.0	98.0	203.0	60.0	44.0	10.0	3.0	2.0	41.0
2	Alabama Port	6.5	1.0	9.5	1.0	3.0	128.0	232.0	162.0	202.0	9.0	6.0	24.0	79.0
12	Little Point Clear	1.0	1.0	0.5	5.0	6.0	26.0	160.0	85.0	47.0	35.0	8.0	3.0	40.0
1	Beacon No. 4	5.0	6.0	10.0	88.0	3.0	52.0	344.0	207.0	58.0	162.0	45.0	9.5	103.0
	AVERAGE	16.7	27.7	4.6	9.4	16.8	229.6	169.0	77.5	30.3	42.0	11.8	9.0	59.0
							P. setiferus							
7	Devil's Channel	0	0	0	0	0	0	0	886.0	2.0	84.0	0	0	130.0
6	Dog River	0	0	28.0	5.0	9.0	8.5	437.0	788.0	95.0	42.0	2.0	1.0	205.0
8	Daphne	0	0.5	0	0	1.5	0	1.7	14.0	4.0	6.0	4.5	0	3.0
5	Deer River	112.0	54.0	14.0	0	8.5	0	107.0	122.0	56.0	206.0	580.0	40.0	124.0
9	Dredge	2.5	0	0	0	0	0	177.0	312.0	74.0	422.0	240.0	0	125.0
4	Fowl River	0.5	1.0	29.0	18.0	5.0	0.5	226.0	62.0	9.0	4.0	18.0	10.0	41.0
10	Mullet Point	0	10.0	8.5	1.0	4.5	0	1.0	4.0	4.0	70.0	14.0	0.5	14.0
3	Beacon No. 18	6.5	89.0	3.0	2.5	3.0	1.0	91.0	28.0	5.0	2.5	2.0	34.0	25.0
11	Bon Secour	1.5	10.0	8.0	9.5	3.0	0	19.0	49.0	5.5	40.0	23.0	5.0	17.0
2	Alabama Port	39.0	48.0	54.0	12.0	1.0	1.0	2.0	134.0	90.0	31.0	24.0	14.0	47.0
12	Little Point Clear	0.5	15.0	12.0	1.5	4.0	1.0	0.7	494.0	28.0	26.0	32.0	22.0	84.0
1	Beacon No. 4	7.5	5.0	0.5	0	1.0	1.0	0	31.0	0	6.5	10.0	11.0	8.0
	AVERAGE	14.2	20.3	13.1	4.2	3.3	0.3	105.2	247.1	31.2	78.0	78.9	11.4	67.2
	TOTAL DRAGS	24.0	23.0	24.0	24.0	24.0	23.0	36.0	48.0	27.0	24.0	24.0	24.0	325.0

TABLE 3.

Various trawl data of white shrimp catch relationships in Mobile Bay, Alabama.

Month	g	a^1/A	W_c	$W_c/a^1/A$	$4370 \cdot w_c$	W_c/g
January	0	–	–	–	22,000	–
February	0.2	0.005	0	insuf	26,000	0
March	32.0	0.078	770	5,872	22,000	24
April	17.0	0.041	63	1,536	13,000	4
May	69.0	0.167	260	1,557	9,000	4
June	397.0	0.962	318	330	1,000	1
July	708.0	1.716	669	390	100,000	1
August	685.0	1.660	97,256	59,793	267,000	111
September	444.0	1.076	99,599	92,564	66,000	208
October	316.0	0.766	82,783	108,072	105,000	262
November	246.0	0.596	58,749	98,572	113,000	238
December	51.0	0.124	12,588	101,516	18,000	247

g = average number of 24-hour fishing days in Mobile Bay (1956–60)
a^1 = sum of areas swept by trawl of entire fleet in Mobile Bay (1956–60)
A = total area of Mobile Bay
a^1/A = number of times area equal to a^1 is swept by trawls in Mobile Bay (1956–60)
W_c = average pounds of shrimp caught commercially in Mobile Bay (1956–60)
$W_c/a^1/A$ = computed crop of shrimp in pounds available to trawls at a given time during a given month as estimated from swept areas (1956–60)
w_c = pounds of shrimp caught with 23 ft-trawl dragged for 30 minutes at 12 bay stations (July 1953–Sept. 1955)
$4370 \cdot w_c$ = computed crop of shrimp in pounds available to trawls at a given time during a given month as estimated from experimental trawling (July 1953–Sept. 1955)
W_c/g = average pounds of shrimp tails caught per day commercial trawling (1956–60)

Part of the difference can be attributed to the fact that these data were also obtained from fresher northern Mobile Bay which was closed to commercial shrimping, and perhaps another part may be attributed to the schooling habits of white shrimp which the experimental methods by chance sampled in concentrations during this month. During December commercial catches indicated a much larger population of white shrimp than actually existed in Mobile Bay because the shrimp were concentrated and commercial boats worked in those areas. Good individual catches are made in cold weather and fishing effort is expended only during times when catches might be good.

Because very young white shrimp stay at the extreme shoreward edge of the water, it is impossible to project the nearshore data as was done for the brown shrimp. Considering the number available as indicated by minnow seine catches, it is obvious that white shrimp were available in approximately the same order of magnitude as were brown shrimp, but for a much shorter period of time, including only late July, August, and September.

If statistics reported the effort directed towards each species, a better estimate could be made of the availability of each species. However, except for the few months where major discrepancies have been noted, standing crop estimates obtained by experimental and by commercial data are of the same order of magnitude. These figures are more accurate for a particular species at the times when that species is being commercially pursued.

The number of white shrimp increased sharply in July and August, decreased in September and increased in October and November, then decreased to practically none in June (Table 2). Gunter (1950) reported a similar seasonal change in Texas. The most productive stations for white shrimp were: Dog River (station 6), Devil's Channel (station 7), Dredge (station 9), and Deer River (station 5). These four most productive stations are all located in the upper end of Mobile Bay. The following stations continue in order of decreasing abundance of white shrimp: Little Point Clear (station 12), Alabama Port (station 2), Fowl River (station 4), Beacon No. 18 (station 3), Bon Secour (station 11), Mullet Point (station 10), Beacon No. 4 (station 1), and Daphne (station 8).

Almost all of the white shrimp caught in the experimental period were taken during the last six months of the year, while the majority of brown shrimp were taken from May through September (Loesch 1962, Table 8). Almost 7000 white shrimp and less than 2000 brown shrimp were taken in hauls in water less than 2 feet deep. Only 326 white shrimp and over 4300 brown shrimp were taken in drags in water from 2 to 10 feet deep.

Pink Shrimp

During the entire survey, only 262 pink shrimp *P. duorarum* were caught in Mobile Bay. These were all taken from October to May. All pink shrimp caught in October and November were taken in the lower end of the bay.

In the 1953–54 winter season, 62 pink shrimp were caught in the sampling trawls; in the 1954–55 season 200 pink shrimp were taken. In 1956, according to U. S. Fish and Wildlife Service statistics, Mobile Bay produced 475 pounds of pink shrimp, all in May. In March 1957 examination of

several commercial catches of shrimp from Mobile Bay showed pink shrimp comprising about one-third of the catch. More than 34,000 pounds of pink shrimp were caught in Mobile Bay in 1957. The following year 2086 pounds of pink shrimp were reported caught in Mobile Bay. Apparently the presence of pink shrimp in large numbers in Mobile Bay is sporadic. Springer and Bullis (1954) report that pink shrimp appeared abundantly in Mississippi coastal waters in 1950 but that they were practically non-existent in catches the previous year and the following three years.

CONCLUSION

Shrimp are subjected to intense fishing pressure in Mobile Bay. During June, July, August, and September the commercial catch of brown shrimp each month may exceed the amount available to the trawl at a given time during that month, as estimated from both experimental data and commercial statistics. About half the available white shrimp are taken each month from August to December. Large numbers of small shrimp are available to replace those caught. It is apparent that shrimp populations have very high recuperative properties due to the fast growth rate and are able to withstand high fishing pressure.

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Biology and Distribution of the Macrocoelenterates of Mississippi Sound and Adjacent Waters

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BIOLOGY AND DISTRIBUTION OF THE MACROCOELENTERATES OF MISSISSIPPI SOUND AND ADJACENT WATERS*

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ABSTRACT Studies conducted in Mississippi Sound from April 1971 through June 1973 elucidated the seasonal and areal distribution of seven species of macrocoelenterates: *Aurelia aurita* (L), *Chrysaora quinquecirrha* (Desor 1848), *Pelagia noctiluca* Forskål 1775, *Chiropsalmus quadrumanus* (Müller 1859), *Rhopilema verrillii* (Fewkes 1887), *Stomolophus meleagris* L. Agassiz 1862, and *Physalia physalis* (L). Physical parameters presumed relevant to the distribution of each of these animals are presented. Developmental histories of certain of these forms are described.

INTRODUCTION

Although there are no recorded instances of dire human encounters with coelenterates along the northern coast of the Gulf of Mexico, the imminent development of the offshore barrier islands as National Park playgrounds introduced the eventuality of human encounters with potentially virulent medusae. Such prospects prompted an intensive investigation of the seasonal and areal distribution of the several large species of jellyfishes presumed inimical toward man's recreational or commercial activities along the northern Gulf coast.

Few studies have been made concerning the biology or distribution of any of the several species of large virulent medusae common to the northern coast of the Gulf of Mexico. The first accounts of scyphozoan medusae collected within the Gulf of Mexico were recorded by Mayer (1900), and Mayer (1910). Hedgpeth (1954) essentially reiterates Mayer's findings and notes the occurrence of two species of scyphomedusae unknown to the earlier author. Whitten et al. (1950) noted the occurrence of three species of Scyphozoa off the Texas coast. Similarly, Gunter (1950) and Simmons (1957) listed a few species of scyphozoan medusae from the waters of Texas. Hoese et al. (1964) provided data concerning the periodic occurrence of *Cyanea capillata versicolor* at Port Aransas, Texas. Guest (1959) and Phillips and Burke (1970) treated the presence of cubomedusae in the waters of Texas and Mississippi, respectively. Burke (1975) noted the occurrence of ten species of Scyphozoa in Mississippi waters.

Sanders and Sanders (1963) in proposing a new subspecies of *Pelagia noctiluca* provided pertinent morphometrics on this oceanic medusa which is, under certain weather conditions, fairly common along the northern Gulf coast. Menzel (1971) in a third edition checklist related the occurrence of five species of scyphozoan medusae and the siphonophore *Physalia physalis* in the waters of Apalachee Bay and St. George Sound, Florida. Christmas (1973) discussed three species of scyphomedusae known to occur within Mississippi Sound. Phillips et al. (1969) elaborated on the ecological role of certain species of Mississippi medusae, and felt that the trophic impact of some of the larger forms must be considerable.

AREA DESCRIPTION

Mississippi Sound is a shallow, elongate body of water, extending from Lake Borgne, Louisiana on the west, to Mobile Bay, Alabama on the east. It is bounded to the south by a series of five low, sand barrier islands. Six passes, three of which are maintained for purposes of navigation, connect the Sound with the open Gulf of Mexico. Coastal sections of three states, Louisiana, Mississippi and Alabama, constitute the northern boundary of the Sound. Fresh water drains into Mississippi Sound via four major watersheds: the Pearl River drainage, St. Louis and Biloxi Bays, and the East and West Pascagoula Rivers. Further influxes of fresh water are derived from the Lake Pontchartrain-Lake Borgne area and from the Mobile Bay complex.

Since Mississippi Sound is essentially a shallow lagoon traversed by deeper passes and drowned river valleys, vertical, areal and seasonal variations in salinity are occasionally extreme. Further, because of Mississippi Sound's temperate location, shallow discolored waters, seasonally changeable wind patterns and inconstant cycles of river discharge, water temperature represents a variable physical parameter.

The sub-tidal bottoms of Mississippi Sound for the most part are soft, sticky muds. Sandy substrata are found adjacent to the barrier islands to the south, and along the man-made sand beaches of the Mississippi mainland. Solid substrata are scarce and are limited to viable oyster reefs, scattered dead valves, debris and man-made structures.

SAMPLING TECHNIQUES

To determine the macrocoelenterate communities indigenous to the barrier islands of Mississippi Sound, monthly trawling routines along the north and south shores of each island were initiated in April 1971 and terminated in June 1973.

The standard otter trawls utilized for such efforts were 16-ft wide semi-balloons made of 1-inch stretch-mesh nylon. Trawls were dragged at each station for 30 minutes at an approximate speed of 3 knots. All macrocoelenterates collected

*This study was conducted in cooperation with the Department of Commerce, NOAA, National Marine Fisheries Service, under Public Law 89-720, Project No. JF-2-8.

in trawls were preserved in 5% formalin-seawater solutions and were taken to the laboratory for identification, counts and measurement. Additional coelenterate specimens were frequently collected with dip-nets.

Concurrent with the monthly trawl hauls executed along the shores of each barrier island, visual surveys were conducted by walking and collecting all stranded jellyfish specimens along the mile of shoreline adjacent to the trawling sites. These specimens were preserved and taken to the laboratory where, if decomposition did not preclude identification, measurements and counts were made.

Since earlier sampling programs had indicated that the cnidaria of Mississippi Sound were recruited from the Gulf of Mexico, efforts were made to quantitate the induction of such forms, as larvae, i.e., ephyrae or early postephyrae. Hence monthly samples were taken from the passes between the barrier islands off the Mississippi and Alabama coasts with 12-inch Clarke-Bumpus bottom plankton samplers equipped with 500-micron netting. Monthly hauls at each site were of an hour's duration and in most cases sampled the entire width of the pass. The samples obtained were carefully examined for ephyrae in the field and were maintained live for microscopic examination in the laboratory. Following meticulous examination, all plankton samples were preserved in 10% formalin-seawater and 48-hour settle volumes were determined.

After August 1971, monthly surface and bottom plankton samples and bottom trawl samples were collected from various bays along the mainland to monitor coelenterate production and infestations deep within the estuary.

Sites were selected in St. Louis Bay, Bay of Biloxi, East and West Pascagoula River systems, and Grant's Pass (Pass aux Herons) in Mobile Bay, Alabama. Bottom plankton sampling and bottom trawl sampling were conducted in fashions identical to those detailed for the original sampling sites. Surface plankton sampling was conducted using a conventional 12-inch surface net equipped with 500-micron netting.

Since the sampling procedure varied as the program progressed, the schedule of site visitations and concomitant efforts are indicated in Table 1, and all sampling sites are indicated in Figure 1.

Simultaneous with biological sampling at each site, temperature, salinity, dissolved oxygen, pH, and transparency were determined. Additionally, the tide stage, prevailing winds, and general weather conditions were recorded. Critical parameters were ascertained as follows:

(1) Temperature: Surface and/or bottom temperatures were determined with either standard mercury-filled, hand-held thermometers or with a Beckman Model RS5-3 salinometer. All readings were recorded to the nearest 0.1°C.

(2) Salinity: Salinity was determined by using refractometers (A O Instrument Company, Models 10402 and 10419) or a Beckman Model RS5-3 portable electrodeless induction salinometer. The refractometers were read to the nearest part per thousand (ppt) while the salinometer was read to the nearest 0.1 ppt.

(3) Oxygen: Dissolved oxygen concentrations were determined by using either a portable oxygen meter (Yellow Springs Instrument Co., Model 54), or the Alsterberg (Azide) modification of the Winkler titration technique.

(4) pH: Water samples were collected at the site and level of each biological sampling effort with standard 1-liter Kemmerer bottles. The samples were subsequently iced or frozen and transported to the laboratory where pH was determined with a Corning Model 10 expanded scale pH meter.

(5) Transparency: Water transparency was estimated by lowering a standard 30-cm diameter, white Secchi disc to its extinction point. The results were recorded to the nearest half foot.

Insofar as bottom type can be properly regarded as a physical parameter of import in determining the distribution of the sessile stages of scyphomedusae, a series of experiments was conducted to ascertain the ability of sessile stages of noxious coelenterates to develop on substrata characteristic of Mississippi Sound bottoms.

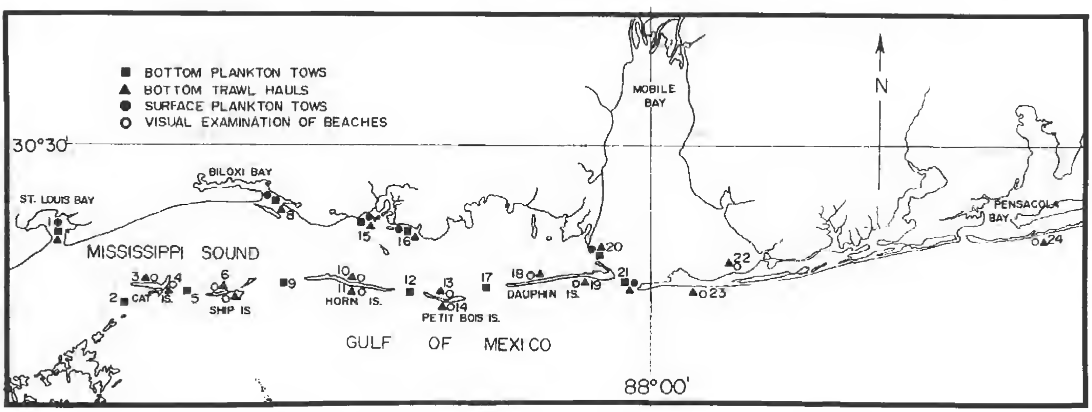

Figure 1. Coelenterate sampling sites in the northern Gulf of Mexico, April 1971–June 1973.

TABLE 1.

Schedule of site visitations and concomitant sampling efforts during the course of the coelenterate sampling program in Mississippi Sound and adjacent waters, April 1971–June 1973.

1 = 30-minute bottom trawl haul
2 = 60-minute surface plankton haul
3 = 60-minute bottom plankton haul
4 = 1-mile visual survey of beach adjacent to trawl site
– = no sample for month

	Station																							
Year/Month	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1971																								
April	–	–	1,4	1,4	1,3	1,4	1,4	–	1,3	1,4	1,4	1,3	1,4	1,4	–	–	–	–	–	–	–	–	–	–
May	–	–	1,4	1,4	1,3	1,4	1,4	–	1,3	1,4	1,4	1,3	1,4	–	–	–	–	–	–	–	–	–	–	–
June	–	–	–	–	1,3	1,4	1,4	–	1,3	1,4	–	1,3	1,4	1,4	–	–	–	–	–	–	–	–	–	–
July	–	–	1,4	1,4	1,3	1,4	1,4	–	1,3	1,4	1,4	1,3	1,4	1,4	–	–	–	–	–	–	–	–	–	–
August	1,2,3	–	1,4	1,4	1,3	1,4	1,4	–	1,3	1,4	1,4	1,3	1,4	1,4	–	1,2,3	1,3	–	–	–	–	–	–	–
September	1,2,3	1,3	1,4	1,4	1,3	1,4	1,4	1,2,3	1,3	1,4	1,4	1,3	1,4	1,4	1,2,3	1,2,3	1,3	–	1,4	–	1,2,3	–	–	–
October	1,2,3	1,3	1,4	1,4	1,3	1,4	1,4	1,2,3	1,3	1,4	1,4	1,3	1,4	1,4	1,2,3	1,2,3	–	1,4	1,4	1,2,3	1,2,3	1,4	1,4	1,4
November	1,2,3	1,3	–	1,4	1,3	1,4	1,4	1,2,3	1,3	1,4	1,4	1,3	1,4	1,4	1,2,3	–	1,3	–	1,4	–	1,2,3	1,4	1,4	1,4
December	1,2,3	3	1,4	1,4	1,3	1,4	1,4	1,2,3	1,3	1,4	1,4	1,3	1,4	1,4	1,2,3	1,2,3	3	1,4	1,4	1,2,3	1,2,3	1,4	1,4	1,4
1972																								
January	1,2,3	3	1,4	1,4	3	1,4	1,4	1,2,3	3	1,4	1,4	3	1,4	1,4	1,2,3	1,2,3	3	1,4	1,4	–	–	–	–	1,4
February	1,2,3	3	1,4	1,4	3	1,4	1,4	1,2,3	3	1,4	1,4	3	1,4	1,4	1,2,3	1,2,3	3	1,4	1,4	1,2,3	1,2,3	1,4	1,4	1,4
March	1,2,3	3	1,4	1,4	3	1,4	1,4	1,2,3	3	1,4	1,4	3	1,4	1,4	1,2,3	1,2,3	3	1,4	1,4	1,2,3	1,2,3	1,4	1,4	1,4
April	1,2,3	3	1,4	1,4	3	1,4	1,4	1,2,3	3	1,4	1,4	3	1,4	1,4	1,2,3	1,2,3	3	1,4	1,4	1,2,3	–	1,4	1,4	1,4
May	1,2,3	3	1,4	1,4	3	1,4	1,4	1,2,3	3	1,4	1,4	3	1,4	1,4	1,2,3	1,2,3	3	1,4	1,4	1,2,3	1,2,3	1,4	1,4	–
June	–	3	1,4	1,4	3	1,4	1,4	1,2,3	3	1,4	1,4	3	1,4	1,4	1,2,3	1,2,3	3	1,4	1,4	1,2,3	1,2,3	1,4	1,4	1,4
July	1,2,3	3	1,4	1,4	3	1,4	1,4	1,2,3	3	1,4	1,4	3	1,4	1,4	1,2,3	1,2,3	3	1,4	1,4	1,2,3	1,2,3	1,4	1,4	1,4
August	1,2,3	1,3	1,4	1,4	3	1,4	1,4	1,2,3	3	1,4	1,4	3	1,4	1,4	1,2,3	1,2,3	3	1,4	1,4	1,2,3	1,2,3	1,4	1,4	1,4
September	–	3	1,4	1,4	1,3	1,4	1,4	1,2,3	1,3	1,4	1,4	3	1,4	1,4	1,2,3	1,2,3	3	1,4	1,4	1,2,3	1,2,3	1,4	1,4	1,4
October	1,2,3	3	1,4	1,4	3	1,4	1,4	1,2,3	3	1,4	1,4	3	1,4	1,4	1,2,3	1,2,3	3	1,4	1,4	1,2,3	1,2,3	1,4	1,4	1,4
November	–	1,3	1,4	1,4	3	1,4	1,4	–	3	1,4	–	–	–	–	–	–	–	–	–	–	–	–	–	–
December	1,2,3	3	1,4	1,4	3	1,4	1,4	1,2,3	1,3	1,4	1,4	3	1,4	–	1,2,3	1,2,3	3	–	1,4	–	–	–	–	–
1973																								
January	–	3	1,4	1,4	3	1,4	1,4	–	3	1,4	1,4	3	1,4	1,4	–	–	3	1,4	1,4	1,2,3	1,2,3	1,4	1,4	–
February	1,2,3	3	1,4	1,4	3	1,4	1,4	1,2,3	3	1,4	1,4	3	1,4	1,4	1,2,3	1,2,3	3	1,4	1,4	1,2,3	1,2,3	1,4	1,4	1,4
March	–	–	1,4	1,4	3	1,4	1,4	–	3	1,4	1,4	3	1,4	1,4	–	1,2,3	3	1,4	1,4	1,2,3	1,2,3	1,4	–	–
April	–	3	1,4	1,4	3	1,4	1,4	–	3	1,4	1,4	3	1,4	1,4	–	–	3	1,4	1,4	–	–	–	1,4	–
May	–	3	1,4	1,4	3	1,4	1,4	1,2,3	3	1,4	1,4	3	1,4	1,4	–	–	3	1,4	1,4	1,2,3	1,2,3	1,4	1,4	–
June	1,2,3	3	1,4	1,4	1,3	1,4	1,4	1,2,3	3	1,4	1,4	3	1,4	1,4	1,2,3	1,2,3	3	1,4	1,4	1,2,3	1,2,3	1,4	1,4	1,4

Muds from Mississippi Sound were forced through sieves of three mesh sizes: 1 mm, 500 μ and 250 μ. Subsamples of the resulting four fractions were placed in glass aquaria containing artificial seawater. Planulae or detached polyps of the following species: *Cyanea capillata versicolor, Chrysaora quinquecirrha,* and *Aurelia aurita* were placed in small, all glass aquaria.

Developmental responses of each species maintained on the various substrata were observed and recorded for periods of time up to 2 months. Long-term developmental norms for the three species were determined by maintaining specimens for up to 1 year when attached to oyster shells or to glass slides.

Since experimentation disclosed the inability of scyphozoan polyps to develop on the silt-like material characteristic of Mississippi bottoms, and field investigations had failed to demonstrate the presence of these sessile forms on existent reefs within the Sound, fouling plates were introduced and artificial reefs were constructed in the areas of higher salinity waters near each of several of the Gulf passes.

Cleaned oyster shells were strung at 1-foot intervals on 80-lb test monofilament lines. Small anchors were attached to the lower ends of the strings and the entire assemblies were held in a near vertical position through the action of surface floats. Additional shell strings were affixed to aids to navigation or other appropriate structures in the area. Such devices were employed in this study as early as June 1971. However, the maintenance of fouling plates in the island passes proved impracticable because of losses resulting from the high incidence of commercial trawling, destruction of navigation aids by barges and other such unwieldy vessels, or removal or destruction by fishermen or pleasure boaters.

Since no polyps were observed on the fouling plates and because of the futility of maintaining them, small reefs were built at stations 4, 9 and 12 in April 1972. Each reef consisted of 125 cubic feet of cleansed oyster valves. Samples were taken by tonging at as close to monthly intervals as weather permitted and were meticulously examined in the laboratory for scyphopolyps.

Concurrent with field and laboratory investigations during the study period, regular contact was maintained with the eight general hospitals in the Mississippi coastal area, and with 14 private physicians in an attempt to monitor jellyfish-inflicted injuries serious enough to warrant professional medical attention.

RESULTS

Seven cnidarian species, represented by 5,704 specimens, were collected in the course of trawling operations during the study period. An additional 5,696 specimens were collected from the sea wrack along the islands adjacent to the trawling sites.

The seven species identified, in order of descending abundance, were:

(1) *Stomolophus meleagris* L. Agassiz 1862
(2) *Crysaora quinquecirrha* (Desor 1848)
(3) *Physalia physalis* (L)
(4) *Pelagia noctiluca* Forskål 1775
(5) *Aurelia aurita* (L)
(6) *Chiropsalmus quadrumanus* (Müller 1859)
(7) *Rhopilema verrillii* (Fewkes 1887)

An appropriate systematic account of the above species is given in Table 2. Individual records of the more abundant species are presented in Tables 3–6, inclusive.

INDIVIDUAL ACCOUNTS OF COLLECTED SPECIES

Stomolophus meleagris, almost always present in Mississippi Sound in varying numbers, was most abundant during midwinter. Specimens were collected which ranged in size from 3.0 to 380 mm bell diameter, suggesting that a few of these medusae may survive for longer than 1 year. *Stomolophus,* although not particularly virulent, is occasionally so abundant that is causes difficulties for commercial trawling operations. The records of *S. meleagris* collections are presented in Table 3.

Chrysaora quinquecirrha, tolerant of wide variations in salinity, is apparently able to survive only during the warmer months along the northern Gulf of Mexico. An irritating stinger, this medusa is most abundant during July and August, but may be collected from March through November.

Although *Crysaora* is a bane to swimmers and fishermen, there were no authenticated accounts of medical treatment for injuries caused by it in the study area. Records of *C. quinquecirrha* collections are shown in Table 4.

Aurelia aurita occurs along the northern Gulf coast during the colder months of the year as revealed in Table 5. Because of its seasonal distribution it is rarely encountered by swimmers and, since *Aurelia* is not particularly virulent, it causes no serious problems for commercial fishermen along the coast.

Chiropsalmus quadrumanus, the most venomous stinger occurring along the northern coast of the Gulf of Mexico,

TABLE 2.

Systematic account of the macrocoelenterates collected in Mississippi Sound and adjacent waters, April 1971–June 1973.

Phylum: Cnidaria
  Class: Hydrozoa
    Order: Siphonophora
      Sub-Order: Cystonectae
        Family: Physaliidae
          Physalia physalis (L)
  Class: Scyphozoa
    Order: Cubomedusae
      Family: Carybdeidae
        Chiropsalmus quadrumanus (Müller 1859)
    Order: Semaeostomeae
      Family: Pelagiidae
        Pelagia noctiluca Forskål 1775
        Chrysaora quinquecirrha (Desor 1848)
      Family: Ulmaridae
        Aurelia aurita (L)
    Order: Rhizostomeae
      Family: Rhizostomidae
        Rhopilema verrillii (Fewkes 1887)
      Family: Stomolophidae
        Stomolophus meleagris L. Agassiz 1862

TABLE 3.

Trawl collection record for *Stomolophus meleagris* in Mississippi Sound and adjacent waters, April 1971–June 1973.

(Parenthetic numbers indicate stranded specimens per mile of beach adjacent to trawl site.)

	Station																							
Year/Month	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1971																								
April					1	1(3)	3(1)				10(1)			3										
May						(2)					1(1)													
June																								
July																								
August																								
September		1		1							21		1											
October																			(1)					
November																			1					
December						(1)			(1)		1		(2)						(5)				(3)	
1972																								
January				(18)		(44)				1(1)				1				(1)						
February																								
March																								
April																								
May																								
June								92																
July																								
August																1					1			
September																								
October																		(1)						
November			(2)	(1)			(4)			(4)														
December						(40)	9(112)		33	1(1097)	16													
1973																								
January				1		2(458)	2(409)				7			2				3				(1)	(1)	
February	1		(1)			(132)				(488)	1(584)		(5)									(1)		
March						(3)	(46)			(7)	(9)			(11)										
April			(1)	5		1(24)	(118)			(167)	(3)		(2)	(9)					1				(2)	
May										(5)	(4)													
June																								

TABLE 4.

Trawl collection record for *Chrysaora quinquecirrha* in Mississippi Sound and adjacent waters, April 1971–June 1973.

(Parenthetic numbers indicate stranded specimens per mile of beach adjacent to trawl site.)

	Station																							
Year/Month	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1971																								
April																								
May							1		73	7	19													
June					19	5						3												
July			1			1								83										
August	55			(16)	8		5(1)		11		135(6)	50		162		4								
September		2	1	7	4	(32)	4		2		263	115	2	17					62		1			
October		1	7		54		4	2	276				3	1		2	3		3					9
November								1											3				6	
December																								
1972																								
January																								
February																								
March																								
April																		3						
May						(4)				4	2(2)			90			7				6	4		
June							59	46		1	94		(2)	(1)		14		(1)	1		24	(1)	30(1)	
July	1					1	2				6				1	35		1		2	35	6	13(1)	10
August		40	5		(1)	1	39	146			3		5(25)		46	109	2	4	383	13		8	65(1)	216
September				1	1	12	46	1		3	1			8				7	1	9	2		5(1)	318
October						2	16				13								2					
November							1						2											
December																								
1973																								
January																								
February																								
March																								
April																								
May				1			1				11			49							1			
June				7	5	3	18			1			4	3					1		1		11	

TABLE 5.

Trawl collection record for *Aurelia aurita* in Mississippi Sound and adjacent waters, April 1971–June 1973.

(Parenthetic numbers indicate stranded specimens per mile of beach adjacent to trawl site.

Year/Month	Station																							
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1971																								
April																								
May																								
June																								
July																								
August																								
September																	10							
October		6	(31)	3(15)	19		2		18(1)		1(1)	1	(6)	(7)			2						(1)	42(12)
November		14		12(5)		(37)	5		20	(1)		31	11	21(4)					108				1	4
December			(3)	3	3	2(14)	1							1									4	
1972																								
January																								
February																								
March																								
April																								
May																								
June																								
July																								
August																								
September											1							2			2			
October				1		(6)					3			1(1)					1					3
November																								
December							(1)		1		4		1											
1973																								
January																			3				1	
February																								
March																								
April											(1)													
May																								
June																								

TABLE 6.

Trawl collection record for *Chiropsalmus quadrumanus* in Mississippi Sound and adjacent waters, April 1971–June 1973.

	Station																							
Year/Month	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1971																								
April																								
May																								
June																								
July																								
August					3																			
September			1	3					2		12	12	3	19			1							
October		4		4	32		13		84			1		1										
November									2															
December																								
1972																								
January																								
February																								
March																								
April																								
May																								
June																								
July																								
August		6	1				1				1													
September				30		1	26			3	13		1				1				1	1		
October			3	1		27	16				1													
November										1														
December																								
1973																								
January																								
February																								
March																								
April																								
May																								
June																								

was collected only during the late summer and fall months. Apparently, having an affinity for deeper, high-salinity waters, it was only rarely encountered along mainland shores. The frequency of occurrence of this animal along the barrier islands, coupled with the almost complete transparency of these medusae, suggests that *C. quadrumanus* could pose a hazard to unwary swimmers. Collection data concerning this organism are defined in Table 6.

Physalia physalis, the Portuguese man-of-war, an open Gulf form, is swept onto the barrier island beaches under fortuitous combinations of wind and current. During May 1971, 102 specimens were collected at stations 4, 6 and 11; while stations 7, 19, and 23 yielded 1426 specimens during December of the same year.

During March, April and July 1972, only 59 man-of-war were found and these occurred at stations 10, 13, 14 and 23.

In 1973 *Physalia* was observed in March and 17 specimens were collected on the beaches adjacent to station 10. All specimens of *Physalia* collected were removed from the beaches adjacent to the corresponding sampling stations (Figure 1).

Intact specimens of *Physalia* do not reach the mainland beaches because their tentacles are abraded as the animals drift through the shallow waters of Mississippi Sound.

Pelagia noctiluca, the mauve stinger, is strictly an oceanic form which occurs in Mississippi Sound only erratically. When long-term incursions of high-salinity waters into Mississippi Sound occurred, these medusae were abundant. *Pelagia* are incapable of prolonged survival within the estuary and are usually moribund when encountered there.

During September 1971, one mauve stinger was collected by trawl at station 11, and a second specimen at station 17. Station 24 yielded 100 specimens to a single 30-minute trawl haul during November 1972.

A swarm of *Pelagia* occurred in the northern Gulf of Mexico in June 1973, with standard trawling yielding a total of 1123 specimens from stations 3, 7 and 11. The presence of 82 specimens in a Clarke-Bumpus bottom plankton sample taken at station 12 (June 1973) demonstrated the local high density.

Rhopilema verrillii is rare along the northern Gulf coast. This organism is of interest in that, even though innocuous, it probably achieves the greatest size of any medusae catalogued from this area. Only eight viable specimens were collected during this study. During April 1971, trawling yielded one specimen from station 11 and four from station 14. Single specimens were collected July 1971 and December 1971, from stations 13 and 12, respectively. The other live specimen was collected at station 9 in December 1972.

During April 1971, visual surveys of beaches adjacent to stations 10, 13 and 14 disclosed one, two and four stranded specimens of *Rhopilema*, respectively. A single beached specimen was taken near station 11 in May 1971.

In January 1973, single specimens of stranded *Rhopilema* were recovered from stations 4 and 6, and two from near station 7. A single specimen of *Rhopilema* was found beached adjacent to station 14 in March 1973.

PLANKTON ANALYSIS

Concurrent with trawling operations, plankton samples were regularly collected within mainland bay areas and in the passes between the barrier islands. Microscopic examination of 224 bottom plankton samples and 102 surface plankton samples failed to disclose ephyrae or early postephyrae of any coelenterate species. The absence of such larval forms indicates that the cnidarian fauna of Mississippi Sound is recruited from an offshore population. The schedule followed in securing plankton samples is shown in Table 1.

HYDROLOGICAL PARAMETERS

Extreme variations in physical parameters were encountered owing to the far-flung nature of the sampling sites and to the inherently fluctuant character of shallow sounds.

Temperatures in the study area followed a fairly predictable seasonal cycle averaging about 12°C during the winter and reaching a summer average of about 30°C. Temperature extremes of 8.9°C and 32.6°C were observed during the study period.

Salinities in the study area ranged from fresh in the upper bay areas to oceanic in the island passes during intrusions of Gulf water.

There was a demonstrable suppression of salinity in the western Sound during the spring and summer of 1973 because of extensive flooding and the concomitant opening of the Bonnet Carré Spillway in the Mississippi River. Salinity extremes of 0.0 ppt and 37.0 ppt were encountered during the study period.

Dissolved oxygen concentrations and pH values generally fell within a range presumed biologically acceptable. All critical hydrographic data are shown in Figure 2.

DEVELOPMENTAL STUDIES OF SCYPHOZOA FROM THE NORTHERN GULF OF MEXICO

Planulae stripped from *Rhopilema verrillii* and *Aurelia aurita* readily produced ephyrae under laboratory conditions. Planulae of *Chrysaora quinquecirrha* were not obtainable either by stripping or by crowding adult medusae into small volumes of seawater, although such efforts were repeated throughout the season. However, with the discovery of polyps and pedal cysts of *Chrysaora* along the barrier islands, partial developmental studies for the species were completed. Experimental studies were continued with polyps of *Cyanea capillata versicolor* collected during the winters of 1968 and 1969. The developmental histories of these four species are presented in Table 7.

A series of substrate preference studies showed that none of the above species were capable of developing normally on particles smaller than 250 μ. Although both *Chrysaora* and *Aurelia* responded to the silt substrate by secreting a broad, adhesive base, neither survived longer than 8 weeks.

Conversely, none of the scyphozoan species utilized the

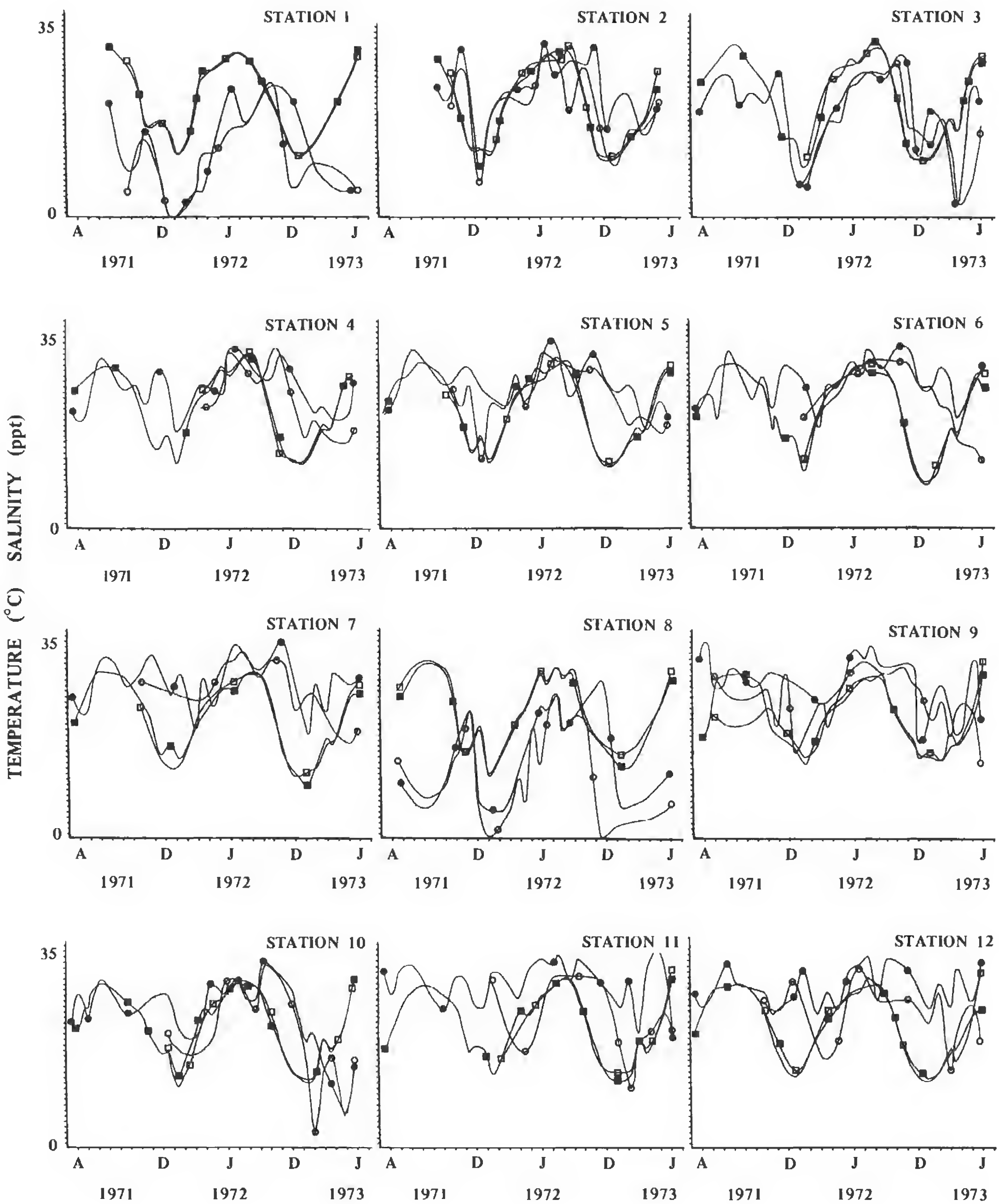

Figure 2. Surface and bottom temperatures and salinities associated with coelenterate sampling sites along northern Gulf of Mexico, April 1971–June 1973. ○ = surface salinity, ● = bottom salinity, □ = surface temperature, ■ = bottom temperature. (Page 1 of 2)

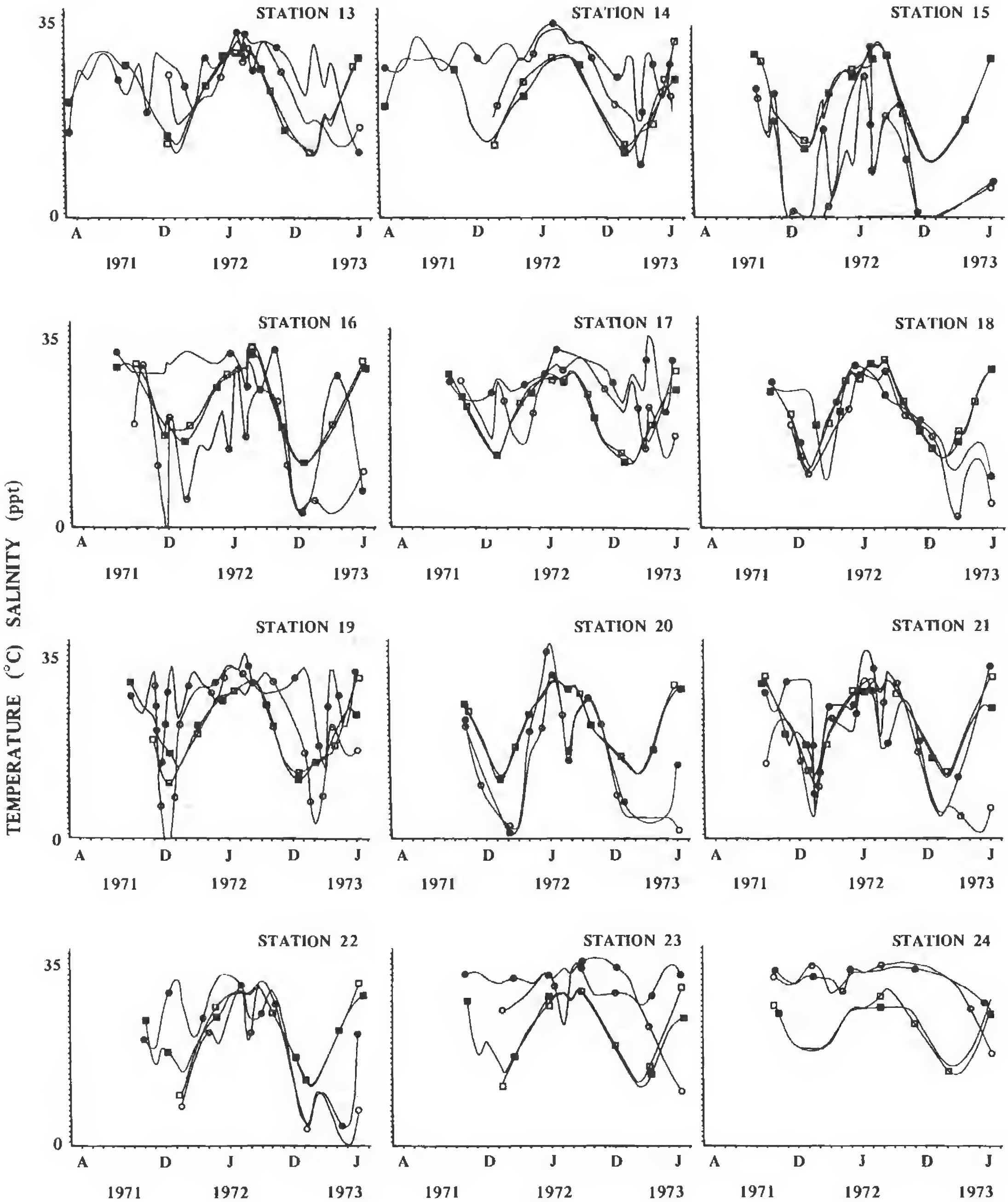

Figure 2. Surface and bottom temperatures and salinities associated with coelenterate sampling sites along northern Gulf of Mexico, April 1971–June 1973. ○ = surface salinity, ● = bottom salinity, □ = surface temperature, ■ = bottom temperature. (Page 2 of 2)

TABLE 7.

Typical developmental patterns of four species of northern Gulf of Mexico scyphozoa.

Species	Temperature	Salinity	Typical Developmental Pattern	Time
C. capillata	13°C	20 ppt	planula – cyst – polyp – podocyst – strobila – ephyrae	9–14 mo.
R. verrillii	13°C	35 ppt	planula – polyp – died	6 days
R. verrillii	18°C	35 ppt	planula – polyp – strobila – ephyrae and/or podocysts	90 days
R. verrillii	22°C	35 ppt	planula – polyp – strobila – ephyrae and/or podocysts	90 days
A. aurita	22°C	35 ppt	planula – polyp – strobila – ephyrae	90–120 days
C. quinquecirrha	22°C	30 ppt	polyp or podocyst – strobila – ephyrae	8 days

fouling plates or artificial reefs provided in the island passes. Enigmatically, cysts and polyps of *Chrysaora* regularly occur in the deeper concavities of mollusc valves found in the swash or in the surf along the Gulf side of the barrier islands. These podocysts are typically found in the valves of such high-salinity forms as *Anadara* sp., *Busycon* sp., *Oliva* sp., and *Arca* sp., suggesting that the Gulf race of *Chrysaora* is probably neritic in habit.

MEDICAL INQUIRIES

Of eight general hospitals and 14 practicing physicians along the coast with whom frequent communication was made, none reported treatment of patients with jellyfish-inflicted wounds. Presumably, these data would be accurate since many of the cooperating physicians proffered accounts of treating wounds inflicted by salt-water catfish and rays.

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Technique for Estimating Trawl Efficiency in Catching Brown Shrimp (*Penaeus aztecus*), Atlantic Croaker (*Micropogon undulatus*) and Spot (*Leiostomus xanthurus*)

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TECHNIQUE FOR ESTIMATING TRAWL EFFICIENCY IN CATCHING BROWN SHRIMP (*PENAEUS AZTECUS*), ATLANTIC CROAKER (*MICROPOGON UNDULATUS*) AND SPOT (*LEIOSTOMUS XANTHURUS*)

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ABSTRACT Mark-recapture experiments conducted in a small 17.5 ha lake in Barataria Bay, Louisiana, were used to estimate the efficiency of a 4.9-m (16-foot) otter trawl in capturing brown shrimp, Atlantic croaker, and spot in water 1.5 m deep. The trawl was observed to sweep an area 2.5 m in width. Trawl efficiency was determined to be approximately one-third to one-half for brown shrimp, one-fourth for Atlantic croaker, and only 6 percent for spot.

INTRODUCTION

The shrimp trawl, often used as a biological tool to estimate the standing crop of shrimp and slow-swimming demersal fish, is not 100% efficient. Loesch (1962) estimated that in Mobile Bay during the months of July, August, and September, an area equal to 1.1 to 1.7 times the total area of Mobile Bay was swept each month by shrimp trawls. During each of these months more shrimp were landed than the estimated standing crop in the area at any one time. This indicates that the shrimp trawl is inefficient at capturing shrimp, that shrimp grow at an extremely fast rate during these periods, or that both of these contributed to this observation.

No study with which we are familiar effectively quantifies the efficiency of a type of collecting gear for capturing a given species. Watson (1976 in press) found that electrical trawl efficiency on burrowed brown and pink shrimp varied from 35% with one net having a small electrical field to 54% with another net having a larger electrical field. Each net was within 5% of its estimated efficiency as predicted from laboratory experiments. Seidel (1972) estimated that working shrimp boats caught approximately one-fourth to one-half of the shrimp in the area covered. Gear efficiency probably varies not only for each species but also for different length classes within each species and with the design of the gear, the method used, the water temperature, the tidal stage and time of day, the behavior of the organism, the turbidity of the water, the bottom type, etc. (see Ko et al. 1970 for a discussion of shrimp behavior near a moving net). While the gear efficiency estimates in this study are pertinent only to the area and the conditions of the study, they may be applied to similar physical environments.

This study estimates the trawl efficiency for two species of fish, *Micropogon undulatus* and *Leiostomus xanthurus*, and one species of shrimp, *Penaeus aztecus*. Trawl locations are given in Figure 1. Water depth ranged from 1 to 1.5 m over a muddy bottom during the period of maximum utilization of the estuaries by juveniles of these species (May 1971, May 1972).

Gear efficiency is defined as the percentage of the organism in the test area (path of the trawl) captured by the gear being used.

METHODS

Laboratory Experiments

Short-term, mass fish-marking experiments have been conducted successfully by the use of compressed air and fluorescent pigments (Jackson 1959; Phinney et al. 1967). Benton and Lightner (1972) used similar techniques and found a 5% mortality after blasting them at 240 pounds per square inch (psi). Preliminary laboratory experiments were conducted to ascertain the optimum pigment-application pressure and the retention time of the imbedded particles. Initially, we marked penaeid shrimp and croaker with fluorescent pigment using 80, 100, and 120 psi pressure from an unmodified paint spraygun. The dry granular pigment was obtained from Wildlife Supply Company[1] of Saginaw, Michigan and was sandblasted into the test organisms. Eight penaeid shrimp were marked at each test pressure and placed in separate aquaria for observation. Controls consisted of 24 shrimp, handled in a similar manner except for spraying, that were divided equally among three aquaria. After 2 days no fluorescent granules were observed on the fish or shrimp when irradiated with UV light. Because there was some clogging of the spray apparatus, the intake stem of the aspirator was removed for subsequent marking. Shrimp were next sprayed at 115, 135, and 155 psi; all retained some detectable fluorescent pigment after 3 days. These results were not considered suitable for field studies, so higher application pressures were tested. One shrimp sprayed at 135 psi molted after the pigment application, but retained the fluorescent dye for at least 3 days after molting. Apparently the dye granules were "sandblasted"

[1] Wildlife Supply Co., Saginaw, Michigan, produces a specially designed air blast gun for marking.

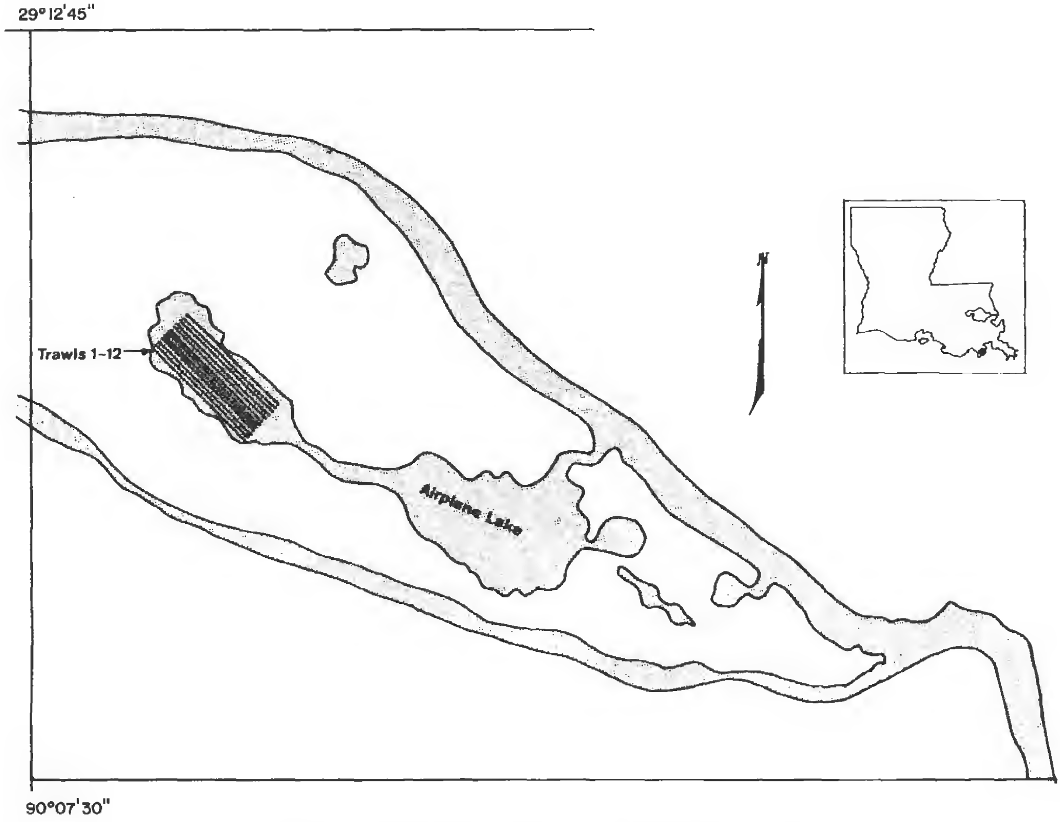

Figure 1. Airplane Lake, Louisiana, and trawl stations for 1972.

through the exoskeleton into the flesh of this individual. Benton and Lightner (1972) stated that pigment granules were located in the exoskeleton, in the paired appendages and tissues of test animals. Many shrimp retained this mark for 2 months while undergoing several molts.

To conserve air and to obtain a more uniform application of dye, a double stage regulator was used for the remaining test pressures (earlier experiments employed a single-stage regulator). Eight shrimp were marked at 165, eight at 200, and eight at 245 psi. One day later, all of the shrimp sprayed at 245 psi were dead; three that were sprayed at 200 psi had molted, and one of the 200-psi shrimp had disappeared (presumably cannibalized). Six days later all live 200-psi test shrimp were sacrificed; all had retained their marks. In another trial, pigment was applied to ten shrimp at 215 and then at 230 psi; about half the shrimp died within hours. Thus, it was decided to apply the pigment at 200 psi. Similar experiments revealed that an application pressure of 150 psi was optimum for marking spot and croaker.

During 1971, 100 shrimp caught near Airplane Lake, Louisiana, on May 13 were marked and kept in 75-liter containers as controls. The containers were new plastic garbage pails that had been aged in seawater. While being held at Grand Isle, Louisiana, the four containers of shrimp were aerated with a Silent Giant aquarium aerator; four battery-powered aerators were used during the trip to Baton Rouge. On May 14, ten shrimp were examined and nine had retained their mark. On May 15, 10 more were examined, all of which had their mark. The marked shrimp were then transported to Baton Rouge for further observation; however, most of the shrimp died en route. During the same period, 101 unmarked shrimp were also kept, most of which also died en route to Baton Rouge. The method of control proved faulty in that live shrimp were sacrificed; no record could be made of shrimp that molted and were cannibalized.

Field Experiments

The inner lobe of Airplane Lake, a small 17.5 ha marsh pond in the Barataria Bay area of Louisiana, was sampled to estimate the populations of the subject species. A sample of the population of each species was obtained by trawl capture

in 12 parallel, 200-m drags. Stakes were placed to designate capture and release sites and to mark each trawl area. Trawling began on one side of the lake and progressed systematically across the lake in order to avoid trawling in previously sampled areas (see Figure 1). Nine and one-half and 12 200-m tows were made in 1971 and 1972, respectively. Sampling began at 0700, and each drag lasted approximately 3 minutes.

Live animals in a small dip net were held in the air about 1/2 m from the nozzle of the spray gun and marked. The spraying procedure lasted approximately 30 seconds. Benton (personal communication) said about spraying, "A trough was constructed with plastic webbing. Shrimp were placed in the trough, and the trough was agitated during spraying so that the shrimp were more evenly covered. The spraying procedure was completed in about 10 seconds." After the animals were marked, they were put in water-filled, plastic garbage cans and observed for a short period. Animals showing no sign of injury were released in the same area from which they were captured.

The recapture method consisted of making parallel, 200-m drags, covering the distance in 3 minutes. Twelve drags were made daily for 7 days. A 16-foot Boston Whaler with an 80-hp Mercury outboard motor was used to tow the trawl. Because it is a cul-de-sac, the lake is not affected by tidal currents. Shrimp, croakers, and spot were separated from the rest of the catch and transported to the field station near Grand Isle, a 15-minute boat ride. They were examined on a tray under ultraviolet light in a specially built darkbox. Each shrimp could be individually handled under the light to separate the marked from the unmarked.

The population of each species was calculated using the Peterson method, $\hat{P} = m(u + r)/r$ (Robson and Regier 1971) where P is the total number of shrimp (or fish) in the population, m the number of marked shrimp in the population, u the number of unmarked shrimp captured in the sample, and r the number of marked shrimp recaptured in the sample. $\hat{P}$ is the estimate of P. This estimate was assumed to be a measure of true population in the lake.

Another estimate based on the swept area of the trawl was derived by the proportion method. Because a 4.9-m (16-foot) trawl does not sweep an area 4.9 m wide, the net's true opening had to be ascertained. First, the distance between floats attached to the trawl boards while trawling was measured by observers in the water. Second, various lengths of twine were tied to the boards. (Twine shorter than the width of the net opening broke, while twine longer than the width did not.) Third, the net opening was measured by a person swimming beside the boards as the net was towed. The average of all computing methods was 2.5 m. Twenty-two measurements were obtained and varied from 1.5 to 3.0 m.

Stakes 100 m apart marked the trawl route and 200 m were covered per sample. Thus each haul swept 500 m² of the lake bottom. In 12 such hauls the trawl covered 6,000 m² of the lake bottom, sampling almost one-tenth of the total of 62,480 m² in the inner lobe of the lake. If the trawl is assumed to be 100% efficient and the distribution of the species uniform, then the total population of the species may be calculated. For instance, 695 spot were captured in this swept area on the first day, consequently we estimated that there were 7,237 spot in the entire inner lobe of the lake.

$$\frac{6{,}000\ \text{m}^2}{62{,}480\ \text{m}^2} = \frac{695}{x};\ x = 7{,}237$$

To determine distribution of shrimp over the lake bottom, an analysis of variance (Table 1) in a random block design was computed on the total 1972 shrimp catch data (Table 2) for each 200-m drag. Blocking removed any differences among days. Shrimp were significantly more abundant near the shore (stations 1 and 12, which are within 10 m of the shoreline), but no differences in density were found among stations 2–11. Because all areas of the lake were sampled equally (Figure 1) and each day's sampling covered the same areas, we feel that the greater densities nearshore do not affect the trawl-efficiency estimate.

Only 423 shrimp were marked in 1972 (as compared to 1,522 in 1971), apparently because fewer shrimp were

TABLE 1.

Analysis of Variance of 1972 Shrimp Catch (Data from the 12 Trawl Stations)

Source	df	Mean Square	F
Days	3	18,631	26.6**
Trawls	11	2,297	3.2**
Trawls 1 and 12 vs 2–11	1	19,729	28.2**
Trawls 2–6 vs 7–11	1	1,988	2.8
Error	33	699	

**Significant at 0.01 level

TABLE 2.

Shrimp catch data 1972 (no. of shrimp)

Date	1	2	3	4	5	6	7	8	9	10	11	12
22 May	33	19	18	53	33	46	45	25	08	15	65	63
23 May	182	105	113	110	102	74	89	96	70	87	88	138
24 May	127	98	126	113	83	100	84	95	76	92	108	237
25 May	185	127	129	166	120	94	134	117	107	103	43	140
TOTAL	527	349	386	442	338	314	352	333	261	297	304	578

present on the day that they were being collected for marking than on subsequent days.

Each day the mark-recapture and swept-area estimates were calculated. The efficiency of the trawl was estimated by dividing the swept-area estimate by the mark-recapture estimate.

On May 16 the estimate of shrimp population using the swept area method was 34,423 and using the population mark-recapture method was 86,588; therefore the estimated trawl efficiency was 34,432/86,588 = 39.8%.

RESULTS AND DISCUSSION

Atlantic Croaker and Spot

Trawl efficiency was calculated for the Atlantic croaker in 1971 and for the spot in 1972 (Table 3). The percent efficiency is an estimate of the percentage of croaker and spot which the trawl captures from the total population calculated to be present in the area swept by the trawl.

The mark-recapture population estimate and the swept-area population estimate would be equal if the trawl were 100% efficient. But if the estimate derived from the swept area is only one-fourth that derived from mark-recapture, and if the mark-recapture estimate is assumed to be the true population, then we can conclude that for the test species and test conditions the trawl is 25% efficient.

It appears that the trawl is more efficient for capturing croaker than it is for spot. This could be related to the differing ecological niches of these two species. The croaker feeds on, and remains close to, the bottom most of the time while the spot is usually found at moderate depths (Nelson 1969). Because the trawl fishes approximately the bottom meter of the water column, the croaker is more vulnerable to capture than the spot. Also, the spot may more successfully avoid the trawl than the croaker.

We estimated that the trawl captured 26% of the croakers and about 6.5% of the spot in the area fished, under conditions that existed at the time (Table 3). Only one sample was utilized for croaker because of the paucity of recaptures in samples on subsequent days. The three estimates for spot show some variation in the estimated efficiency (Table 3).

Shrimp

Only the first day or two of shrimp recaptures in 1971 can be used in claculations (unless corrections are made) because on each successive day the number of marked-recaptured shrimp dropped drastically, causing the population estimate from the mark-recapture to increase rapidly (Table 4), while the population estimate from the swept area remained fairly constant. If the population estimate from the swept area remains constant, one would expect the same consistency among the marked-recaptured shrimp, unless the shrimp were losing their marks, or were being selectively eliminated from the overall population either by differential rate of mortality, by migration, or by shedding of the mark. It is suspected that shrimp were losing their marks at the rate of about 15% per day.

The estimated population of brown shrimp (Table 4) in the swept area varied only from 34,423 to 30,714 on May 14, 15, and 18, but the number estimated from mark-recaptures increased sharply from 86,588 to 146,496. Based on these figures, the efficiency of the 4.9-m trawl, which opened to 2.5 m wide while fishing, varied from 40% to 21%. We assume that the data of the first two days are the most reliable, and that the trawl was about one-third efficient for brown shrimp under these conditions.

Estimated population in the swept area during May 1972 varied from about 13,000 to 15,000 (about half that of May 1971); it increased slowly during the sampling time. The percent efficiency of the trawl varied from about 27% to 13% in 1972. Because the population from the swept area remained fairly constant, while the number of marked shrimp recaptured decreased with time during the two successive years, it might be assumed that something was happening to the marked shrimp. Most control shrimp in earlier experiments retained their marks, but they were not exposed to predation, except cannibalism.

When the shrimp population as calculated by the swept area method consistently decreases while the population as calculated by the mark-recapture method increases rapidly (Table 4), then some of the marked shrimp are disappearing from the population in the lake. Although trawl efficiency is expected to remain constant, calculation using these data suggests that it decreased from 39.8% to 8.4% in 10 days of sampling (Table 4).

We presumed that the trawl efficiency would not vary consistently (becoming less efficient each day) as was indicated by using the data that assumed no marks were lost (Table 4). We then calculated an estimated 10% mark loss

TABLE 3.

Population Estimates and Percent Efficiency of Trawl from Mark-Recapture

Species	Date	Number Marked At Large	Number Marked Recaptured	Number Unmarked Captured	Swept Area (m^2)	Swept Area Estimate No. Fish	Mark-Recapture Estimate No. Fish	Trawl Efficiency (%)
Atlantic Croaker	13 May 1971	149						
Atlantic Croaker	14 May 1971		3	156	4750	2065	7,798	26.5
Spot	22 May 1972	695						
Spot	23 May 1972	695	6	715	6000	7237	83,516	9.0
Spot	24 May 1972	689	3	498	6000	5217	115,063	4.5
Spot	25 May 1972	689	4	404	6000	4249	69,972	6.1

TABLE 4.

Population Estimates and Percent Efficiency of Trawl from Mark-Recapture of Brown Shrimp, *Penaeus aztecus*

								If 10% Marked Lost Each Day			If 15% Marked Lost Each Day		
Date	Number Marked at Large (m)	Number Marked Recapt. (r)	Number Unmarked Captured (u)	Swept Area (m^2)	Pop. Swept Area	Pop. Mark-Recapt.	% Trawl Effi-ciency	Number Marked at Large (m)	Pop. Mark-Recapt.	% Trawl Effi-ciency	Number Marked at Large (m)	Pop. Mark-Recapt.	% Trawl Effi-ciency
1971													
14 May	1522	46	2571	4750	34,423	86,588	39.8	1370	77,941	42.8	1294	73,617	46.7
15 May	1476	33	2446	4750	32,608	110,879	29.4	1192	89,544	36.4	1061	79,704	40.9
18 May	1443	23	2312	4750	30,714	146,496	21.0	845	85,786	35.8	632	64,162	47.9
19 May	1420	14	1804	4750	23,913	184,397	13.0	740	96,094	24.9	518	67,266	35.5
24 May	1406	9	1376	4750	18,218	216,368	8.4	434	66,788	27.3	224	34,446	52.9
1972													
23 May	423	11	1243	6000	12,996	47,799	27.2	381	43,326	30.0	360	37,571	34.6
24 May	412	5	1334	6000	13,943	110,334	12.6	333	89,177	15.6	297	79,537	17.5
25 May	407	6	1459	6000	15,256	106,159	14.4	295	72,029	21.2	248	60,553	25.2

13 May 1971 — 1522 shrimp marked
22 May 1972 — 423 shrimp marked

per day (Table 4) and found that estimated trawl efficiency still decreased daily. Presuming that a greater loss of marks must be occurring, we calculated the estimated trawl efficiency assuming a 15% mark loss. When a daily loss of marked shrimp was calculated, the percent trawl efficiency for 1971 varied (not regularly) from 36% to 53% with an average of 44.8% (Table 4). Using these data it seems that the shrimp trawl we used was from one-third to one-half efficient under the conditions that existed. Population estimates of brown shrimp in subdelta Louisiana estuarine areas based on sampling with a 4.9-m trawl should incorporate this one-third to one-half efficiency estimate.

With refinements, we believe this method can be used to estimate the true population of aquatic animals present in an area at any given time. This study was designed to determine approximate trawl efficiencies for shrimp, croakers, and spot in the area. Similar procedures for other species in different habitats at other times of the year would be expected to yield different gear efficiencies. A larger trawl and increased turbidity may improve gear efficiency. We do believe that the method holds some promise for determining the percentage of fish a particular gear captures.

CONCLUSIONS

One important point emerges from these results, i.e., the 4.9-m otter trawl is much less than 100% efficient. It captured approximately 26% of the croakers, 6% of the spot, and 30–50% of the brown shrimp from the study area. These species are probably more susceptible to capture than are most others because they are slow-moving demersal forms. Biomass estimates based on swept area using trawl data are therefore minimal and a conversion factor must be applied before estimating the true standing crop.

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A BIBLIOGRAPHY OF ANOMALIES OF FISHES: SUPPLEMENT 3

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ABSTRACT This third supplement adds 158 titles to "A Bibliography of Anomalies of Fishes," which was originally published in this journal in 1964; the first supplement followed in 1966 and the second supplement, in 1971. Citations now total 1498 in the series.

This listing adds 158 titles to those of the original bibliography and previous supplements [*Gulf Res. Repts.* 1(6), 1964; ibid. 2(2):169–176, 1966; ibid. 3(2):215–239, 1971]. Of these, 124 were published during the 1970–75 period. A total of 1498 citations are now included in this series.

As in previous supplements, titles are serially numbered and prefixed by the letter "S"; the prefix is omitted from index listings. Corrections to be made in previous sections are indicated under Corrigenda.

We wish to express our continued appreciation to colleagues providing reprints of their papers or otherwise contributing to this project.

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TAXONOMIC INDEX

INDEX OF ANOMALIES

CORRIGENDA

The following corrections should be entered in the appropriate sections of the original bibliography and Supplement 2.

Reference	Correction
Title 195	Change: "Anat" to Anstalter.
Title 216	Change date to 1907.
Title 342	To read: Handa.
Title 478	To read: 2(12):205–210.
Title 493	To read: Kobayashi, His.
Title 495	To read: Kobayashi, Hir.
Title S-195	Delete.
Title S-278	Change date to 1964.

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Penaeid Shrimp Distributions in Mobile Bay, Alabama, Including Low-Salinity Records

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SHORT COMMUNICATIONS

PENAEID SHRIMP DISTRIBUTIONS IN MOBILE BAY, ALABAMA, INCLUDING LOW-SALINITY RECORDS

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ABSTRACT Low-salinity records in the Gulf of Mexico area for taking *Penaeus duorarum* in water of 0.7‰ and 28°C, and *Penaeus aztecus* in water of 0.2‰ and 29.5°C were established in Mobile Bay, Alabama. Catches in Mobile Bay of approximately 20,000 each of *P. aztecus* and *Penaeus setiferus*, distributed over a 30-month period, show that *P. aztecus* taken in the hotter months had a wider salinity preference (5 to 30‰) than those taken in the cooler months (10 to 15‰). During the warmer months *P. setiferus* was most common in waters below 5‰ and during the winter months was almost equally distributed in the various salinities. Few *P. duorarum* were taken during the survey.

INTRODUCTION

Twelve stations in Mobile Bay, Alabama (Figure 1) were sampled monthly for 30 months by a standard 30-minute drag with a 7.7-meter lead line shrimp trawl as described in Loesch (1965). Bottom water samples were collected and titrated with silver nitrate in the laboratory for salinity calculations. Loesch (1965) did not discuss relationships between abundance of shrimp and salinity, nor did that paper establish low-salinity records for any species. The present paper is an analysis of shrimp abundance (19,413 brown, 23,161 white, and 235 pink shrimp) in 325 samples as compared to salinity (Table 1, Figure 2).

RESULTS

Gunter et al. (1974) reported that Gunter and Shell (1958) took brown shrimp, *Penaeus aztecus* Ives, at 0.8‰ and characterized this as the lowest salinity in which they had been found on the north coast of the Gulf of Mexico. Gunter et al. (1964) reported them taken at a salinity of 0.22‰ in Florida. Swingle (1971) reported nine brown shrimp caught in Alabama in waters where the salinity ranged from 0 to 0.2‰. Perret et al. (1971) reported 79 brown shrimp taken from the same salinity range in Louisiana. Christmas and Langley (1973) did not collect any brown shrimp from salinities below 0.3‰. On June 10, 1954, four brown shrimp were captured in Devil's Channel south of the Mobile Causeway (station 7) in 0.2‰ salinity and 29.5°C. In the 20 collections made in water with salinities below 1‰, only the June 10 collection contained brown shrimp.

Hoese (1960) took pink shrimp, *Penaeus duorarum* Burkenroad, in 2.7‰ salinity water, which Gunter et al. (1974) reported as the lowest salinity in which they had been taken in the northern Gulf. It had not previously been reported that on April 21, 1955, one pink shrimp was taken in Deer River Channel (station 5) in water of 0.7‰ salinity and 28°C. During that month, when water was unusually

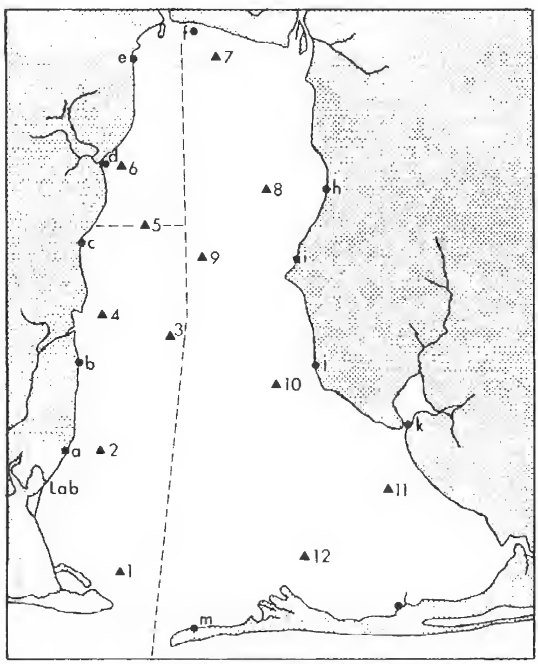

Figure 1. Bay and nearshore stations sampled in Mobile Bay, Alabama.

*Formerly principal marine biologist for the Alabama Conservation Department.

TABLE 1.

Number of shrimp, samples, and shrimp per sample caught in different salinities in Mobile Bay.

	Salinity (°/₀₀)							
	0–5	5–10	10–15	15–20	20–25	25–30	30+	Total
Brown, April–October, 1953–55 – Warm weather (water 21–32°C)								
Total shrimp	1055.0	4058.0	5129.0	2820.0	2434.0	2103.0	339.0	17,938.0
Total samples	46.0	38.0	40.0	40.0	30.0	15.0	4.0	213.0
Shrimp/sample	22.9	106.8	128.2	70.5	81.1	140.2	84.8	84.2
Brown, November–March, 1953–55 – Colder weather (water 8.5–21°C)								
Total shrimp	9.0	20.0	967.0	83.0	213.0	177.0	6.0	1,475.0
Total samples	28.0	19.0	16.0	17.0	18.0	13.0	1.0	112.0
Shrimp/sample	0.3	1.1	60.4	4.9	11.8	13.6	6.0	13.2
White, August–November, 1953; July–November, 1954; July–September, 1955 – Young small shrimp								
Total shrimp	5822.0	3626.0	6783.0	2188.0	1537.0	1540.0	27.0	21,523.0
Total samples	13.0	24.0	26.0	34.0	30.0	22.0	3.0	152.0
Shrimp/sample	447.8	151.1	260.9	64.4	51.2	70.0	9.0	141.6
White, July, 1953; December, 1953–June, 1954; December, 1954–June, 1955 – Somewhat older shrimp								
Total shrimp	256.0	368.0	502.0	192.0	291.0	28.0	1.0	1,638.0
Total samples	61.0	33.0	30.0	23.0	18.0	6.0	2.0	173.0
Shrimp/sample	4.2	11.2	16.7	8.3	16.2	4.7	0.5	9.5
Pink, July, 1953–September, 1955 – All pink shrimp were caught during these months								
Total shrimp	1.0	67.0	118.0	3.0	31.0	8.0	7.0	235.0
Total samples	74.0	57.0	56.0	57.0	48.0	28.0	5.0	325.0
Shrimp/sample	0.01	1.2	2.1	0.1	0.6	0.3	1.4	0.7

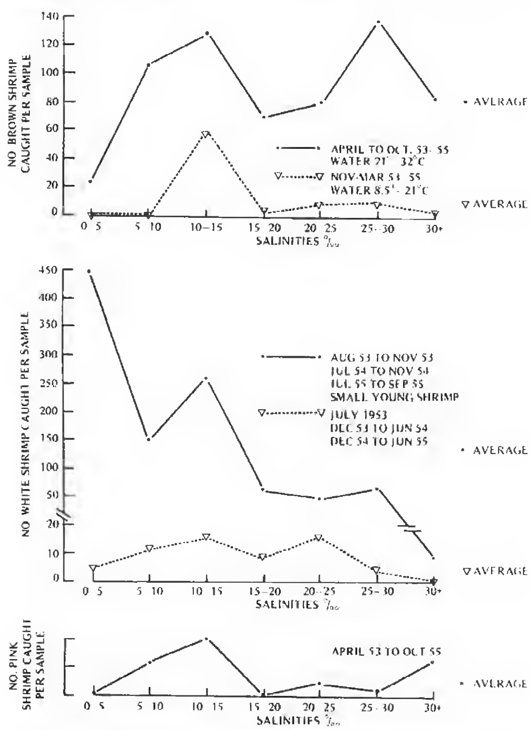

Figure 2. Average catch per sample of three species of shrimp in different salinities during two seasons of the year.

fresh, salinity was recorded at 0.5°/₀₀ as far south as Alabama Port (station 2). Only one white shrimp, *Penaeus setiferus* (L), was taken in salinity below 1°/₀₀, and that was at 0.9°/₀₀ and 29.5°C on 8 August 1955 at Devil's Channel (station 7) in the northern part of Mobile Bay.

DISCUSSION

Statistics

Loesch (1962) statistically analyzed variance of size of both brown and white shrimp and found no significant difference between years for either species. However, as would be expected, there was a highly significant difference between months/years. The bay was divided into four sections, generally from fresher water to more saline water. An analysis of variance for the four chosen locations/months/years also proved to be highly significant. In general, larger shrimp were found in the lower (generally saltier) section of the bay, and shrimp were progressively smaller towards the upper (fresher) section of Mobile Bay. For greater details on the statistical calculations and results, see Loesch (1962, p. 83–94).

Brown Shrimp

The brown shrimp catch in different salinities was calculated for two different periods of the year: from April to October, when temperature ranged from 21° to 32°C, and from November to March, when temperature ranged from 8.5° to 21°C.

During the warm months brown shrimp were common

in salinities from 5 to 30‰. There were two peaks of abundance: one at salinities of 10 to 15‰ and another at 25 to 30‰ (Figure 2). The peak at 25 to 30‰ was caused by two extremely high catches of brown shrimp in July and August 1954 at one always-rich station (station 1) located in deeper water near the mouth of Mobile Bay. In the 15 times this salinity range was sampled, half the shrimp were caught in these two samples.

During the cooler months the majority of brown shrimp taken were in salinities from 10 to 15‰.

White Shrimp

One of the two curves (Figure 2) for white shrimp started with the appearance of the new crop and lasted until most had left the area. This occurred from August to November in 1953, July to November in 1954, and July to September in 1955, when the project terminated.

During the warm months white shrimp were most plentiful in waters of low salinities, especially below 15‰ (Figure 2). During the colder months they were not plentiful at any salinity, and there appeared to be no recognizable relationship between abundance and salinity.

Pink Shrimp

All pink shrimp were caught from October to May. The majority were taken in the lower end of the bay in October and November.

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Growth of the Shrimp, *Penaeus aztecus*, Fed a Diet of Live Mysids (Crustacea: Mysidacea)

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GROWTH OF THE SHRIMP, *PENAEUS AZTECUS*, FED A DIET OF LIVE MYSIDS (CRUSTACEA: MYSIDACEA)

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ABSTRACT Commercial brown shrimp (*Penaeus aztecus*) were shown to consume large numbers of mysid shrimp (*Mysidopsis almyra*) under laboratory conditions. Growth of shrimp fed a diet of mysids was comparable to growth of shrimp fed a diet of *Artemia* nauplii. It is suggested that mysid shrimp may serve as a food source for juvenile penaeid shrimp in northwestern Gulf coast estuaries.

INTRODUCTION

The rapid growth of juvenile brown shrimp (*Penaeus aztecus*) along with their nutritional value and high demand has led to their consideration for mariculture. The artificial foods that have been formulated and tested in the laboratory generally result in growth for juvenile shrimp that is less than that for shrimp fed natural food (Zein-Eldin and Meyers 1973). *Artemia* are generally used as a subsistence or control diet but are not naturally available to shrimp in the estuary. It is suggested that some other crustacean may serve as the major food source for natural populations of shrimp. Because mysid shrimp can be collected along with penaeid postlarvae (Christmas et al. 1966) in large numbers in the shallow estuarine areas during summer months (Conte and Parker 1971), and are known to have a high caloric value (Wissing et al. 1973), they were evaluated in this study as a food for shrimp.

MATERIALS AND METHODS

Four experiments were conducted over the period of August 1973 to June 1974. Experiments were conducted using a variety of glass containers having no substrate and no filtration. Aeration was provided through a single air stone in each container. Brown shrimp were obtained from the hatchery of the National Marine Fisheries Service in Galveston through the courtesy of Mr. C. Mock. They were held a maximum of 1 week in 150-liter aquaria with subgravel filters and fed a commercial flake food (Tetramarin[2]). One liter of artificial sea water (Instant Ocean[2]) per shrimp was provided at 20 ppt and room temperature (ca. 23°C). Illumination from a 40-watt fluorescent lamp was controlled by a timer to give a photoperiod of 14 hours light per day. Mysids (*Mysidopsis almyra*) were collected alive from the marshes of Galveston Island as required and held in a 150-liter aquarium with filtration.

In a preliminary experiment, mysid consumption by three sizes of shrimp was tested (Table 1). Shrimp were placed in separate 1-liter aquaria and each size was replicated. Each aquarium was provided with five mysids. Aquaria were examined every 4 hours for a period of 5 days. The number of mysids consumed was recorded and additional mysids provided to maintain a density of five per aquarium. The average wet weight of a mysid (0.0011 g), based upon 100 determinations, was used to determine the weight of mysids consumed by the shrimp (Table 1).

Due to the difficulty in supplying a sufficient number of mysids for large (60 mm) shrimp, under these experimental conditions and the unavailability of postlarval shrimp, penaeids approximately 30 mm in size were used for growth experiments. In three experiments shrimp were fed an abundance of mysids or *Artemia* nauplii once daily. In an additional aquarium shrimp were not fed. Detritus was siphoned out every other day but the water was not changed during an experiment. Length (tip of rostrum to end of telson) was determined to the nearest mm utilizing Allen's (1963) procedure at the initiation and the termination for individual shrimp in experiment A (Table 2). To avoid handling the shrimp in subsequent experiments (B and C Table 2) length was determined by sacrificing an initial sample and all survivors. In experiment A increase in size of individual shrimp held in 1-liter fingerbowls was determined after 5 days. In experiment B an initial 30 shrimp were placed in each of three 115-liter aquaria. Water was removed from each aquarium to maintain 1 liter per shrimp. Every 5 days for 15 days, 10 shrimp were removed and sacrificed. An attempt was made to capture the smallest and largest shrimp according to the procedure of Zein-Eldin (1963). Five-liter aquaria were used in experiment C to determine increase in size of individual shrimp after 21 days.

RESULTS AND DISCUSSION

The maximum growth rates for *Artemia*-fed shrimp (0.82 mm per day) and for mysid-fed shrimp (0.72 mm per day) were comparable. In one experiment (A, Table 2) the mysid-fed shrimp had a faster growth rate than the *Artemia*-fed shrimp. The lesser growth rate for the mysid-fed shrimp in experiment B (Table 2) possibly was due to the larger area of the aquarium, compared with the fingerbowl, which

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[2] Use of trade names does not imply endorsement.

TABLE 1.

Maximum consumption of mysids by *Penaeus aztecus* over 5 days.

Shrimp Size	Number Consumed	Weight Consumed	Final Weight of Shrimp (g)	Shrimp Weight Consumed (%)	Daily Consumption (%)
10 mm postlarvae	8	0.0088	0.004	220.0	44.0
10 mm postlarvae	14	0.0154	0.010	154.0	30.8
30 mm	65	0.0715	0.26	27.5	5.5
30 mm	60	0.0660	0.28	23.6	4.7
60 mm	109	0.1199	1.24	9.6	1.9
60 mm	95	0.1045	1.07	9.7	1.9

TABLE 2.

Daily growth rate in length (mm per day) of *Penaeus aztecus*.

Diet	Growth Rate (mm/day)	Range in Final Size	No. Shrimp
Experiment A – 5 days in 1-L. fingerbowl			
Unfed	0.08	(32–42)	9
Artemia-fed	0.52	(33–43)	8
Mysid-fed	0.72	(35–45)	7
Experiment B 1st Sample – 5 days in 115-L. aquaria			
Unfed	0.06	(22–32)	10
Artemia-fed	0.46	(24–35)	10
Mysid-fed	0.42	(26–33)	10
2nd Sample – 10 days in 115-L. aquaria			
Unfed	0.13	(25–32)	5
Artemia-fed	0.82	(27–40)	10
Mysid-fed	0.25	(25–35)	10
3rd Sample – 15 days in 115-L. aquaria			
Unfed	–	–	0
Artemia-fed	0.82	(32–44)	10
Mysid-fed	0.35	(27–42)	6
Experiment C – 21 days in 5-L. aquaria			
Unfed	–	–	0
Artemia-fed	0.40	(32–37)	2
Mysid-fed	0.33	(32–34)	2

Avg. daily growth: Unfed–0.09; *Artemia*-fed–0.60; Mysid-fed–0.41.

provided the mysids a greater area in which to evade the shrimp. *Artemia* provided in the other aquarium tended to remain aggregated, thus being more vulnerable to predation. However, in the 5-liter aquaria (experiment C, Table 2) growth of *Artemia*-fed shrimp was poor and the shrimp fed with mysids grew less rapidly than the *Artemia*-fed shrimp.

No unfed shrimp survived longer than 14 days. None of the fed shrimp died during the experiments. Losses occurred due to shrimp jumping out of aquaria during feeding or observation.

Growth in these studies at no time approached the growth rate of 1.5 mm per day reported for brown shrimp in the natural environment (Williams 1955). Growth of shrimp in aquaria is usually less than that expected from nature. Zein-Eldin (1963) using 0.41 liters of water per shrimp and feeding *Artemia* achieved a maximum growth of 0.42 and 0.68 mm per day. Zein-Eldin and Aldrich (1965) achieved a maximum growth rate of 1.11 mm per day on a diet of *Artemia*. The average of the growth rates from the three experiments for *Artemia*-fed (0.60 mm per day) and mysid-fed (0.41 mm per day) shrimp is comparable to the growth rate (0.42 mm per day) reported by Zein-Eldin (1963). By maintaining better water quality and feeding a mixed diet, better growth possibly could be obtained in the laboratory.

While growth in this study did not approach that reported from nature, the growth of mysid-fed shrimp was comparable to that of *Artemia*-fed shrimp. Considering that mysids occur with shrimp in large numbers when the shrimp postlarvae are entering the estuaries, it is suggested that mysid shrimp may serve as a food source for juvenile penaeid shrimp.

ACKNOWLEDGMENT

We wish to express our appreciation to Ms. C. Battle for aid in the preliminary work and to Dr. D. V. Aldrich for his advice and suggestions.

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Activities of the Gulf Coast Research Laboratory During Fiscal Year 1975-76: A Summary Report

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ACTIVITIES OF THE GULF COAST RESEARCH LABORATORY DURING FISCAL YEAR 1975–76: A SUMMARY REPORT

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GENERAL

Mississippi's institution of higher learning for research and education in the marine sciences, the Gulf Coast Research Laboratory received an annual general support appropriation of $1,390,318 for the fiscal year 1976 allocated by the 1975 Mississippi Legislature. This support was augmented by self-generated funds, including grants and contracts, in the amount of $508,365.

RESEARCH VESSEL

Construction of an 85-foot oceanographic research vessel for the Gulf Coast Research Laboratory by International Marine Fabricators, Tampa, Florida, under contract with the State Building Commission, continued until February 1976 when all work ceased. At that time, International Marine Fabricators went out of business, leaving the vessel partially constructed. The State Building Commission is currently studying the entire problem and is expected to proceed with the completion of the vessel upon the acquisition of additional funds.

PHYSICAL PLANT

A two-story addition to the Richard L. Caylor Building neared completion as the year ended. The construction was funded in the amount of $172,000 and supervised by the State Building Commission. When completed, the building will provide a lecture hall on the first floor. The second floor will provide 2,400 square feet of space and will house the administrative offices of the Mississippi-Alabama Sea Grant Consortium.

A new water well was constructed to supplement the existing system that had about reached its limit of supply and to provide for the needs of facilities planned for the future. Further, it increased the supply of water available for fire fighting which was previously inadequate. This project was funded in the amount of $16,500 and supervised by the State Building Commission.

The Laboratory, using institutional funds in the amount of $28,318, constructed a 21x62-foot greenhouse and controlled environment chamber for the Botany Section. This facility significantly expands the Laboratory's research capability and enhances current studies of saltmarsh plants and seagrasses.

The Laboratory acquired, at no cost, approximately 52.0 acres of surplus property consisting of about 6.07 acres of marsh island and 45.83 acres of water bottoms from the Department of Health, Education and Welfare on January 30, 1976. This relatively undisturbed estuarine marsh will be used principally as an experimental study area for graduate students pursuing original research, and for ecological studies, including the periodic monitoring of various environmental parameters by Laboratory investigators.

RESEARCH SECTIONS

During the year, the 15 research sections collectively pursued 124 separate investigations, with progress varying from initial probes to completion. A few selected projects for each section are described briefly below:

ANADROMOUS FISHES SECTION

Striped Bass Rearing and Stocking–Mississippi (Funded by National Marine Fisheries Service, U.S. Fish and Wildlife Service and Gulf Coast Research Laboratory): The final segment of this three-year project was carried out during the year. The overall objective was to establish a viable striped bass population in Mississippi coastal waters.

A total of 446,000 2-inch South Carolina striped bass were laboratory reared and released into local waters, along with 30,000 2-inch bass reared from fish known to migrate into the open sea.

A hatchery was established at the Mississippi Game and Fish Commission laboratory on the Ross Barnett Reservoir near Jackson, Mississippi. Ripe male and female striped bass were captured from the tailrace of the dam, taken to the hatchery and spawned, resulting in 5,000 24-hour-old striped bass fry. A total of 2,670 of these fish were reared to 2 inches in length at the Gulf Coast Research Laboratory and then released into local waters. This was the second consecutive year that striped bass fry were produced from Mississippi brood stock. A sampling program is in progress to check for natural reproduction of previously stocked bass and for the occurrence of juvenile striped bass, and to monitor previously stocked striped bass in order to continue assessing the results of all bass stocking programs previously carried out in this area.

Development of Gulf Coast Artificial Reefs (Funded by Mississippi-Alabama Sea Grant Program): The states of Mississippi and Alabama are currently in the process of placing ten surplus Liberty Ship hulls in eight locations off their coast. A total of nine hulls have been placed in the Gulf at eight locations; two have been sunk off the Mississippi coast at each of two locations. The reefs, monitored bi-weekly by personnel from Mississippi and Alabama, are assessed by diver survey and sport fishing methods. Divers are observing the effects of attraction devices such as automobile tire units and multiple arrays of 10-foot

lengths of 2-inch PVC pipe, attached by one end to the sunken hulls.

Artificial Midwater Reef Development Program (Funded by Mississippi Marine Resources Council and Gulf Coast Research Laboratory): Extensive colonization by hydroids and amphipods has occurred on the attractors (enhancement devices). Large aggregations of desirable pelagic and reef fish have been observed and caught over and in the reefs. Observations of the success of the reefs as attractors are being conducted in conjunction with this project.

Bait Fish Rearing (Funded by Mississippi Marine Resources Council and Gulf Coast Research Laboratory): This study, to be initiated on July 1, 1976, will develop and make available methods for rearing bullminnows in controlled ponds to supply the live-bait industry. The bullminnow is a favorite live bait used when available by many coastal sportfishermen. Supplies are quickly depleted in late fall when the spotted seatrout (*Cynoscion nebulosus*) are running. Bullminnows are supplied to the retail market by a few fishermen using traps and/or hook-and-line.

ANALYTICAL CHEMISTRY SECTION

Sediment and Floral Hydrocarbons of the MAFLA Monitoring Program (Funded by Bureau of Land Management, U.S. Department of Interior): The investigation of the distribution of hydrocarbons in benthic sediments and algae was continued through the project. Samples were collected during two seasons from transects extending around the northeastern Gulf, from Pascagoula, Mississippi, to Ft. Myers, Florida, and out to the edge of the continental shelf. In order to monitor the effects of exploratory drilling done in 1974–75, a larger area was sampled and collections were made over a longer period than were those of a baseline study conducted in 1974, prior to exploration. The study also determined seasonal variations at stations beyond the present lease sites.

Sediment and Floral Hydrocarbons of the MAFLA Rig Monitoring Program (Funded by Bureau of Land Management, U.S. Department of Interior): Twenty-five stations located off Port Aransas, Texas, were sampled before, during, and after the construction of a rig to determine the detrimental effects of rig use. Although the analyses are incomplete, it appears that no pollution effects are discernible. The major advantage of this study was to provide a means of testing the reproducibility of sampling and analysis for sedimentary hydrocarbons.

BOTANY SECTION

A Study of Salt Marsh in Mississippi by Remote Sensing (Funded by Mississippi Marine Resources Council and Gulf Coast Research Laboratory): This project was designed to obtain ground truth data on the vegetation of salt marshes of Mississippi. Surveys were conducted and 40-acre vegetatively homogeneous tracts were selected to be utilized in developing remotely sensed electronic signatures from satellite flights. Small tracts, ranging in size from a fraction of an acre to an acre or more, were selected for low-altitude aircraft flights provided by the National Aeronautics and Space Administration. These flights provided detailed information on the vegetational and ecological aspects of Mississippi salt marshes. This information will ultimately be used to prepare vegetational maps of Mississippi's wetlands.

The Population Dynamics of Juncus roemerianus (Funded by Gulf Coast Research Laboratory): This study was initiated during the year. *Juncus* dominates the marshes of Mississippi and a better understanding of its genetics and productivity are major objectives of the study.

A Phytosociological Study of Horn and Petit Bois Islands, Mississippi (Funded by U.S. National Park Service): This two-year project is scheduled to begin on July 1, 1976. The first year's work will consist of a general survey to locate areas from which to obtain detailed floristic and ecological information during the second year. The study will determine the presence and abundance of each species, define and map habitats, and deal with their ecology.

ECOLOGY SECTION

Three environmental impact statements were drafted during this fiscal year. The first of these was requested by the Jackson County Board of Supervisors for the Ocean Springs, Mississippi, Beach Renewal project. This project called for the dredging of 30,000 cubic yards of sand to replenish 2,800 feet of front beach in Ocean Springs. The other two impact statements were written for the Laboratory. One of these was for the widening and deepening of the docking facilities at Point Cadet, Biloxi, to provide docking space for the new research vessel. The other was necessary in order for the Laboratory to obtain a marsh island in Back Bay of Biloxi from the federal government. A similar document was also prepared on the value of Marsh Point as a natural unaltered marsh area.

Environmental Affairs Committee: The activity of this Committee, composed of the senior scientific staff, is coordinated by the Ecology Section. The Committee coordinates the Laboratory expertise to provide an interdisciplinary focus on environmental problems, impact statements and permit requests for work proposed in the wetlands and estuaries. The latter is a service to the Mississippi Marine Resources Council, which partially funds this work.

Many permit requests were reviewed throughout the year. In addition, an environmental evaluation of dredging operations in the Pascagoula River by Technical Sands, Inc., Moss Point, Mississippi, was conducted from December 3, 1975 through April 9, 1976 for the Mississippi Marine Resources Council.

ENVIRONMENTAL CHEMISTRY SECTION

The Fate and Effect of Oil Pollution in the Marine Environment (Funded by Environmental Protection Agency): The final year of this three-year study, jointly conducted by Mississippi State University, University of Southern Mississippi and the Gulf Coast Research Laboratory, was completed in February of 1976. During the summer months of 1975, the focus of research was four test ponds located at the National Space Technology Laboratory near Bay St.

Louis, Mississippi. Three new crude oils were tested for toxic effects on shrimp, mullet and oysters in these ponds. Both hydrocarbon distributions and concentrations were determined periodically on sediments, water column and plant tissue. A final report has been submitted to the primary contractor, Mississippi State University.

Sediment and Floral Hydrocarbons of the MAFLA Monitoring Program, and Sediment and Floral Hydrocarbons of the MAFLA Rig Monitoring Program (Funded by Bureau of Land Management, U.S. Department of Interior): The Environmental Chemistry Section participated jointly with the Analytical Chemistry Section (see) in these studies.

FISHERIES MANAGEMENT SECTION

Liberty Ship Artificial Reef (Funded by the Mississippi Marine Conservation Commission and Gulf Coast Research Laboratory): During the year two more Liberty Ship hulls were sunk offshore, one of which was located 4 ½ miles south (3HO 35921-3HI 1900) of Horn Island and the other, 12 ½ miles south (3HO 3577-3HI 1907) of Horn Island. The section worked jointly with the Anadromous Section (see) on the artificial reef study. This project is expected to improve recreational fishing in the area for the benefit of the general public.

A Survey of Oyster Reef Populations in Biloxi and Pascagoula Bays (Funded by Gulf Coast Research Laboratory): These reefs have historically produced large quantities of oysters. However, in the 1960's, both areas were closed because of high coliform counts caused primarily by septic tank seepage and improperly operating sewage treatment facilities. In their present locations, the oysters are a liability to the State in that the areas must be patrolled on a 24-hour basis to prevent their illegal removal and use. They also constitute a lost resource unless they can be removed to clean waters where they cleanse themselves by depuration and then can be harvested.

The objectives of the survey included the assessment of the present oyster population on the major closed reefs in order to determine the size range and abundance of the oysters and the locating of a suitable bottom for relaying and subsequent depuration of the oysters. The survey showed that 100 barrels of large oysters were available on the two major closed reefs. It was further determined that, with proper management, an oyster population of this magnitude could be sustained annually. Another aspect of the reef survey revealed in excess of 710 acres of bottom suitable for oyster relaying and depuration.

FISHERIES RESEARCH AND DEVELOPMENT SECTION

Fisheries Resources Assessment and Monitoring, Mississippi (Funded by National Marine Fisheries Service and Gulf Coast Research Laboratory): An extensive sampling program employing trawls, seines, plankton nets and nekton nets has provided data for assessment and monitoring of Mississippi's fishery resources. Monthly reports, published in *Marine Briefs*, have provided real-time information on resource populations. Appropriate segments of this work have been closely coordinated with the National Marine Fisheries Service's research in Gulf waters. Data have been provided to the Mississippi Marine Conservation Commission, Mississippi Marine Resources Council, Mississippi-Alabama Sea Grant Consortium, and to numerous other State and federal agencies and many private entities.

The shrimp sampling program has provided accurate predictions of the commercial fishery production and a scientific basis for management of the shrimp fishery. Estimates based on data from previous years show that the 1975 brown shrimp crop in Mississippi waters was worth approximately $1,000,000 more in dockside value than could have been expected from the same potential in prior years. The June 1976 harvest, according to preliminary reports, probably set a new high record for value and volume. Similar production rates are expected to continue through the season.

Fisheries Planning (Funded by Gulf Coast Research Laboratory): Active participation by the Laboratory provided for the effective input of Mississippi's position in practically all Gulf of Mexico fishery planning activities. These activities involved cooperation with such agencies as the National Marine Fisheries Service, Gulf States Marine Fisheries Commission, the Commission's Technical Coordinating Committee and sub-committees, Gulf State-Federal Fishery Management Board, Sea Grant Association, Mississippi Marine Resources Council, Mississippi Marine Conservation Commission and several professional societies.

The Gulf Coast Research Laboratory was selected to develop management plans for Gulf shrimp and Gulf menhaden and, subsequently, was awarded federal grants totaling $100,000 to develop these plans.

Cooperative efforts with Sea Grant personnel and fishing industries resulted in acceptance by the U.S. Army Corps of Engineers and congressional delegations from the Gulf states of a proposal to study the feasibility of controlled fresh water introduction to estuaries east of the Mississippi River delta.

Fishery Assistance Services (Funded by the Gulf Coast Research Laboratory): Technical assistance was provided in response to numerous calls from local fishing industries, especially bait and crab fishermen, and from the Mississippi Marine Conservation Commission. Up-to-date information on fishery technological problems, regulations, and pertinent pending legislation has been made available to fishermen and the fishing industry.

Statistics on Subsistence Fishing in Coastal Counties of Mississippi (Funded by National Marine Fisheries Service and Gulf Coast Research Laboratory): Investigations continued to determine the level of subsistence fishing in the coastal counties of Mississippi. This study was designed to give an equal amount of attention to all commercially important species and gear types presently managed by the Mississippi Marine Conservation Commission. It is unlike previous surveys of this nature in other states, generally listed as "recreational shrimping" that deal only with one major gear type and usually three common species of shrimp (*Penaeus aztecus*, *Penaeus setiferus*, and *Penaeus duorarum*).

Subsistence fishermen utilize part or all of their catch as a direct food source, thus supplementing the family

income. In instances where the catcher has to travel great distances or use high-powered gasoline engines, the cost per pound of seafood may be high. Preliminary determinations in this investigation indicate the cost per pound in the Mississippi subsistence shrimp fishery to be $1.37. The cost per pound is decreased due to the number of commercial fishermen involved in this study and their use of larger gear and diesel engines and the close proximity of the inhabitants in the coastal counties of Mississippi to the resource.

The commercial shrimp catch from the inside waters of Mississippi is not known precisely, because the statistical areas used by the National Marine Fisheries Service in reporting shrimp landings (*Gulf Coast Shrimp Data*) include portions of Louisiana and Alabama with Mississippi. Total figures for the commercial catch have not been published to date for 1975. Preliminary figures published in Mississippi Landings, indicate a 24-percent drop from 1974 to 1975 for shrimp. Shrimp taken by subsistence fishermen declined 15 percent from 1974 to 1975 (166,667 pounds to 141,757 pounds).

Development of a Fishery Management Plan for Gulf Shrimp (Funded by National Marine Fisheries Service, Gulf States Marine Fisheries Commission, and the five Gulf states): The Gulf of Mexico shrimp fishery, harvesting at least seven species, extending to all parts of the United States Gulf coast, utilizing an extremely diverse fleet of boats and vessels, employing many thousands of people and producing the highest dollar value of any Gulf fishery, is extremely complex. Current management is entirely under State jurisdiction and is limited to territorial waters. Development of an acceptable Gulf-wide management plan, designed to accomplish and maintain optimum sustainable yield from these resources, is essential.

The Gulf States Shrimp Management Plan will contain a clear statement of mission and objectives, utilizing the "Management by Objectives" technique. Problem identification will focus on profile work already completed; i.e., the discussion paper on shrimp fishery management, National Marine Fisheries Service. Problems will be identified by type (administrative, legal, institutional, legislative, biological, technical, economic, social, environmental, etc.), by degree, and homogeneous area (state, international, range of stock, or section of Gulf). Problems will be analyzed, and potential alternative solutions will be developed, which will in turn reflect needs for problem solution. An action program will then be developed to delineate and prioritize the most feasible actions necessary to meet the established mission and objectives.

Funds necessary to implement the proposed actions will be estimated, the appropriate funding source will be identified, as will the responsibility for taking the necessary actions and the potential benefits that may accrue to the fishery if the funds are spent. Priorities for action will be scheduled, as required, for task(s) accomplishment.

A recommended approach for coordinating the management program will be outlined, including the responsibilities for assuring implementation of the plan. A system for monitoring and evaluating the effectiveness of the management program will be designed.

The Gulf Coast Research Laboratory, with the aid of representatives from the Gulf states (Florida Department of Natural Resources, Alabama Department of Natural Resources, Mississippi Marine Conservation Commission, Louisiana Wild Life and Fisheries Commission and Texas Parks and Wildlife Department), National Marine Fisheries Service laboratories and other agencies as appropriate, will develop from existing secondary data and necessary interview data, a concise description of the Gulf shrimp fishery.

Development of a Fishery Management Plan for Gulf Menhaden (Funded by National Marine Fisheries Service, Gulf States Marine Fisheries Commission and the five Gulf states): The Gulf of Mexico menhaden fishery, using a relatively homogenous fleet of large vessels owned and operated by only five companies, harvests the largest volume taken in any U.S. fishery, almost entirely from one species located in the north central Gulf of Mexico. Consequently, development of an acceptable management plan with all companies participating is not expected to be extremely complex. However, there are strong indications that the maximum sustainable yield is already achieved in this fishery and management plan development is urgent.

The Gulf States Menhaden Management Plan will contain a clear statement of mission and objectives, utilizing the "Management by Objectives" technique. Problem identification will focus on profile work already completed; i.e., the discussion paper on menhaden fishery management, National Marine Fisheries Service. Problems will be analyzed, and potential alternative solutions will be developed, which will in turn reflect needs for problem solution. An action program will then be developed to delineate and prioritize the most feasible actions necessary to meet the established mission and objectives.

Funds necessary to implement the proposed actions will be estimated, the appropriate funding source will be identified, as will the responsibility for taking the necessary actions and the potential benefits that may accrue to the fishery if the funds are spent. Priorities for action will be scheduled, as required, for task(s) accomplishment.

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The Gulf Coast Research Laboratory, with the aid of representatives from the Gulf states (Florida Department of Natural Resources, Alabama Department of Natural Resources, Mississippi Marine Conservation Commission, Louisiana Wild Life and Fisheries Commission, and Texas Parks and Wildlife Department), National Marine Fisheries Service laboratories and other appropriate agencies, will develop from existing secondary data and necessary interview data a concise description of the Gulf menhaden fishery. Periodic planning and workshop conferences will be conducted in cooperation with the Gulf States Marine Fisheries Commission.

GEOLOGY SECTION

Mississippi Offshore Inventory and Geological Mapping

Project (Funded by Mississippi Marine Resources Council and Gulf Coast Research Laboratory): This project consisted of mapping and describing sediments of the bottom and subbottom of Mississippi Sound. Additionally, the erosional-accumulation conditions on the mainland, several islands and human activities influencing them were studied.

Geological Cross-Sections Under the Sound (Funded by Mississippi Marine Resources Council): A report with illustrations, completed and submitted in January 1976, will be published in offset print by the Mississippi Marine Resources Council.

Gulf of Mexico Bottom Sediment Analysis (Funded by National Marine Fisheries Service): Analyses of 25 bottom sediment samples were made for the National Marine Fisheries Service at Pascagoula, Mississippi, for their use in correlating with fish habitats for sediment texture types.

Offshore Barrier Island Study (Funded by Gulf Coast Research Laboratory): This project addressed the geological history, genetic conditions and present-day state of six Mississippi-Alabama barrier islands. Corehole drilling was completed on Dauphin Island (three coreholes), Petit Bois Island (three coreholes) and Horn Island (five coreholes) through contractors using thread-mounted rotary rigs. The U.S. National Park Service provided barge transportation. Sediment and micropaleontological analyses of the obtained samples are in progress.

Study of Heavy Mineral Content, Distribution and Origin of Miocene Coastal Sedimentary Units (Funded by Gulf Coast Research Laboratory): Formations play an important part in the makeup of the Mississippi coast and as aquifers. The stratigraphic problems involved are being studied in cooperation with Mississippi Geological Survey.

MICROBIOLOGY SECTION

Pollution Indicator Bacteria Studies in Selected Areas of the Mississippi Sound (Funded by Gulf Coast Research Laboratory): Water samples were collected monthly from 63 stations. Stations were located in Biloxi Bay, in four transects across the Mississippi Sound and on the beaches of Horn and Ship Islands. Samples were subjected to bacteriological analysis for coliforms and fecal coliforms.

Microbiology of Crabmeat and Sanitation in Crab Processing Plants (Funded by Gulf Coast Research Laboratory): Several crab processing plants in Mississippi are being visited regularly to make microbiological evaluations of the quality of their products at each step in processing. In addition, a study is being made of the bacteria associated with crabmeat as it undergoes the spoilage process.

Microbiology of Estuarine Sediments (Funded by Gulf Coast Research Laboratory): Currently, studies are being made of the distribution, taxonomy and ecology of bacteria of the genus *Bacillus* in estuarine sediments.

Persistence and Degradation of Insecticides in Estuarine Water and Sediment (Funded by Gulf Coast Research Laboratory): Investigations have continued regarding the degradation of malathion, parathion, methyl parathion, and diazinon in estuarine water and sediment. Emphasis has been on the metabolism of these organophosphorus insecticides by pure culture bacteria indigenous to the sediment of the Mississippi Sound estuary system. Work involving malathion and parathion has essentially been completed, resulting in various publications. Investigations concerned with methyl parathion and diazinon are in progress.

In addition to studies concerning the organophosphate insecticides, an attempt is currently underway to isolate into pure culture a bacterium or fungus capable of degrading mirex, a chlorinated hydrocarbon insecticide. To date, the microbial degradation of mirex has not been demonstrated.

Insecticide Persistence in Natural Seawater as Affected by Salinity, Temperature, and Sterility (Funded by U.S. Environmental Protection Agency): The objective of this research is to determine the effect of salinity, temperature, and sterility on the persistence and degradation of malathion, parathion, methyl parathion, diazinon, and methoxychlor in natural seawater. Three temperatures (10°, 20° and 30°C) and four salinities (0, 10, 20 and 28 ppt) are employed in these investigations. Results to date indicate that abatement of the organophosphate insecticides is directly proportional to salinity and inversely proportional to increasing temperature. Insecticide disappearance appears to be the result of both chemical and biological mechanisms.

MICROSCOPY SECTION

Some Parasites and Diseases of Estuarine Fishes in Polluted Habitats of Mississippi (Funded by Gulf Coast Research Laboratory): Studies were initiated on a variety of parasites and pathological processes of commercially important fishery species and are still in progress, in collaboration with the Section of Parasitology (see).

Internal Lymphocystis of the Silver Perch (Funded by Gulf Coast Research Laboratory): This study of lymphocystis disease of various internal organs, with emphasis on cardiac lesions, neared completion by the end of the year.

OYSTER BIOLOGY SECTION

Oyster Spat Monitoring Program, Biloxi Bay and Adjacent Waters (Funded by Gulf Coast Research Laboratory): This project is concerned with basic biological research on settlement and growth of oyster "spat" in various areas of Mississippi Sound.

Cestode Parasites of Oysters and Other Edible Mollusks of the Northeastern Gulf of Mexico (Funded by Gulf Coast Research Laboratory): This study dealt with the effects of oyster predators and pathogens.

Biological and Ecological Studies of the Oyster Boring Clam (Funded by Gulf Coast Research Laboratory): This is a study of the effects of boring clams, including their distribution, abundance, reproduction and their effect on Mississippi Sound oysters.

The section was instrumental in making it possible for the Laboratory to establish the first seed oyster hatchery (see) in the Gulf of Mexico region in cooperation with the Mississippi Marine Resources Council. The section has charge of the hatchery which is now operational and continues to

increase its production of seed oysters for research and development projects in Mississippi.

PARASITOLOGY SECTION

Parasites of Commercially Important Fishes (Funded by National Marine Fisheries Service and Gulf Coast Research Laboratory): This project primarily concerns the use of parasites of Atlantic croaker to indicate migratory and feeding behavior of the fish. Feeding habits of several local finfishes are being investigated. The project also covers aspects of the effects of selected parasites on several different hosts.

Parasites of Marine Animals in the Northern Gulf of Mexico (Funded by Mississippi-Alabama Sea Grant Program and Gulf Coast Research Laboratory): This project is divided into studies dealing with parasites infecting finfishes and shellfishes of commercial interest, and those capable of infecting or causing disease in man. The latter studies were concerned with parasites that cause dermatitis and those that can infect or cause disease in man if infected hosts are eaten raw or inadequately prepared.

Studies on Helminths of the Northern Gulf of Mexico Region (Funded by Gulf Coast Research Laboratory): A determination of parasites of hosts was made in this study. It included life histories of the parasites and the relationship between parasites and hosts.

A Study of the Diseases of Fish of Mariculture Potential: Parasites and Parasite-Borne Diseases of Red Sea Mullets (Mugilidae) (Funded by U.S.-Israel Bi-National Foundation): This project was conducted under the auspices of the United States-Israel Bi-National Science Foundation, in collaboration with Dr. Ilan Paperna, Marine Biological Laboratory, The Hebrew University, Elat, Israel.

Because Mediterranean mullets have been maintained successfully in ponds and because disease in those fish is a serious problem, the diseases of Red Sea mullets are being studied to judge their potential in culture. Emphasis also centers around heterophyid infections, since these trematodes can be transmitted to man.

PHYSICAL OCEANOGRAPHY SECTION

Mississippi Sound Hydrographic Study (Funded by Mississippi-Alabama Sea Grant Program and Gulf Coast Research Laboratory): This project has the multiple objectives of: describing the tidal-current patterns; construction of cophase charts; and delineating the distribution of nutrients and salinity. Additionally, much of the tidal and physical constituent data will be employed in the development and calibration of a mathematical model of Mississippi Sound.

Characterization of Tidal Bayou and Development of Statistical Evaluation/Monitoring Techniques (Funded by Gulf Coast Research Laboratory): While much emphasis has been placed on research in open estuarine waters, very little work has been done in the most critical areas, the contributaries—especially the tidal bayous. Data to ascertain the most useful of parametric statistics to characterize the system have been collected for the past two years. In addition to establishing these baseline statistics, statistical techniques are being developed for monitoring the bayous for changes that might ordinarily go unnoticed using the usual methodology.

PHYSIOLOGY SECTION

Studies on the Time Course of Salinity and Temperature Acclimation in Brown Shrimp Penaeus aztecus Ives (Funded by U.S. Army Corps of Engineers): The objective of this study was to determine the rates at which brown shrimp adapt to changing conditions of salinity and temperature. This information was totally lacking and the results are important in basic and applied research, particularly in mariculture. The brown shrimp were tested both by direct transfer from control salinity and temperature conditions and by acclimating them in control salinity maintained at three temperatures. The level of adaptation in different conditions was determined on the basis of attaining a steady state in the regulation of blood osmotic and ionic concentrations and in oxygen consumption rates. In the second phase of this project, a study was made of the effects of deviated ion-ratios in the water media on the survival and behavioral responses of brown shrimp. Also, attempts were made to define the lethal ion-ratio deviations in coastal waters for brown shrimp.

Evaluation of the Nutritional Value of Grass from High Marsh Areas from Brown Shrimp Penaeus aztecus Ives (Funded by Mississippi Marine Resources Council and Gulf Coast Research Laboratory): The objective of this study, to be initiated July 1, 1976 and conducted in conjunction with the Section of Microbiology, is to determine the feasibility of using high marsh grasses as a supplemental feed for young shrimp. Shrimp shell waste from the canning industry will also be evaluated as a nutrient source. Should these experiments provide satisfactory growth rates, it will be possible to prepare food for shrimp and other crustaceans more economically with the available natural ingredients.

Studies on the Molting Frequency of Small Postlarval Brown Shrimp Penaeus aztecus Ives in Relation to Salinity (Funded by Gulf Coast Research Laboratory): The objectives of this study are to determine the role of salinity changes on the molting frequency and resultant growth rates of young brown shrimp. This data will be correlated with behavioral, growth and survival rate data, already obtained from earlier studies, to determine optimal rearing salinities for the various postlarval stages.

SYSTEMATIC ZOOLOGY SECTION

Collections were obtained in the Panama Canal and adjacent areas during January 1976; a trip was made to Belize during April. This work was conducted in cooperation with the Smithsonian Institution.

Systematic and distributional studies continued on the families Microdesmidae, Gobiidae, Dactyloscopidae and Syngnathidae. Reviews of the Indo-Pacific pipefish genera *Corythoichthys* and *Lissocampus* were completed. A large amount of data leading to a synopsis of pipefishes currently

referred to as the genus *Icthyocampus* was accumulated. Work was initiated on studies leading to a review of the Atlantic sand stargazers (Dactyloscopidae). Work continued on the review of Atlantic pipefishes and other long-term projects. In connection with these matters, studies were made on fishes in the collections of the Philadelphia Academy of Sciences and the National Museum of Natural History.

SPECIAL FACILITIES

MARINE EDUCATION CENTER

Visitations to the Marine Education Center have shown a dramatic increase from 13,750 in fiscal year 1975 to 19,675 in fiscal year 1976. With the construction of a larger facility in the future, it is anticipated that the Center will attract in excess of 200,000 visitors annually.

Twenty-one teachers have taken the advanced course, "Advanced Studies in Marine Science for Teachers," offered at the Marine Education Center, and 74 teachers have completed the introductory course, "Basic Techniques in Marine Science for Teachers." A third course, "Marine Science for Elementary Teachers," has been written and approved and is to be offered at a later date.

The Curator of the Center acts as a consultant to Marine Life, Inc., of Gulfport, Mississippi, concerning proper procedures for maintaining local marine animals. In addition, the Curator instituted a research project with a graduate student in an effort to determine the causative agent for "Paisley's Disease" which has infected several of the dolphins owned by Marine Life.

Educational pamphlets for the elementary student have been published concerning the crawfish and the Atlantic bottlenosed dolphin. Future efforts in this area will concentrate on a series treating local game fish.

OYSTER HATCHERY

The Oyster Biology Section completed the design and construction phases of the oyster hatchery in 1975 and it entered an operational testing phase. Hatchery personnel began improving oyster culture techniques, equipment operation and maintenance, technical processes, etc., and integrating them into a functional and operational pilot seed oyster hatchery. Millions of attached and unattached (cultchless) seed oysters are being reared on a continuous basis in the hatchery. The seed oysters being reared now are used for various experimental purposes, including (but not limited to) the following: staff and graduate student field and laboratory experiments, cooperative oyster culture experiments with other state agencies and interested parties, and bioassaying. Excess seed oysters will be used for reef rehabilitation trials.

The seed oyster hatchery is providing evidence that such a culture facility is practically feasible (i.e., is capable of producing millions of attached and cultchless seed oysters) and can play a major role in the development of intensive oyster culture in Mississippi Sound and adjacent waters.

The knowledge gained from the oyster hatchery research will eventually assist the Mississippi Sound oyster industry by increasing production in unpolluted areas or by rejuvenating formerly productive reefs. The hatchery should also demonstrate the commercial potential for private seed oyster hatcheries in Mississippi Sound and the northern Gulf of Mexico. The hatchery's potential as an educational and research facility in the years to come is, perhaps, its greatest value.

THE GUNTER LIBRARY

During the fiscal year, 308 books and 1,212 reprints were accessioned. Numerous back issues of journals were purchased with special Library Improvement Funds appropriated by the Mississippi Legislature. Major gifts from individuals included a personal library valued at $14,000 from Dr. Harry J. Bennett of Louisiana State University, and a collection of 4,500 reprints and separates from Dr. Jean Piatt of the University of Pennsylvania. The personal reprint collection of Dr. Gordon Gunter, Director Emeritus, was placed in the Controlled Circulation section. The reprint cataloging program was revitalized with the assignment of one extra typist and a number of graduate students to the task.

A Library Committee was formed in October 1975 and as a result of their recommendations a six weeks course in Library Science was conducted for the Library assistants and aides. The Committee was also instrumental in the development of modified circulation systems, in acquiring needed equipment, and in setting up the graduate student reprint cataloging program.

ICHTHYOLOGY RESEARCH MUSEUM

The Museum, part of the Systematic Zoology Section, cataloged 1,004 lots of fishes, representing about 10,000 specimens. The total vertebrate holdings now include 14,894 cataloged lots, approximately 140,000 specimens.

A number of loans and exchanges were made with other institutions in the United States and elsewhere. Numerous identifications were made on materials sent by workers in Surinam, Nicaragua, Mexico, Australia, Hawaii, Panama, Samoa and the United States.

Gifts or exchange specimens were received from the National Museum of New Zealand; University of Nicaragua; University of Panama; Western Australian Museum; Zoologische Museum, Kanpur, India; National Museum of Natural History (Smithsonian Institution); California Academy of Sciences and other institutions.

The Museum was designated as one of five major Regional Ichthyological Collections in the final report of the American Society of Ichthyologists and Herpetologists Advisory Committee on collections.

The Gulf Coast Research Laboratory is a member institution of the Association of Systematics Collections.

WATER ANALYSIS LABORATORY

This facility is operated by the Analytical Chemistry

Section. During the year, water analyses were performed for the sections of Physical Oceanography, Botany, Parasitology, Ecology and Anadromous Fishes. In addition, samples were processed for Marine Life of Gulfport, Mississippi. The Mississippi Marine Resources Council contracted for a variety of analyses on waters from the Pascagoula River.

A total of 2,185 separate analyses were conducted, including analyses for nitrate (382), nitrite (358), total phosphorus (382), orthophosphate (382), ammonia (42), salinity (41), chlorophyll (28), phaeophytin (28), DO (4), sulfate (12), total suspended solids (60), pH (53), silicate (24), turbidity (48), alkalinity (29), COD (24), fluoride (24), cyanide (24), Kjeldahl (24), and nine heavy metals (24).

COMPUTER SECTION

The Computer Section underwent an overall streamlining and improvement program, which included the updating of existing data files, development of higher level statistical and graphic programs, production of an ongoing accounting system and the cross-training of all section personnel.

Equipment was acquired to execute, as soon as possible, a tie-in of the Laboratory's IBM 1130 Computer with the Xerox Sigma IX Computer at the University of Southern Mississippi, Hattiesburg.

PUBLIC INFORMATION/PUBLICATIONS SECTION

This Section prepared news releases on a variety of newsworthy subjects and distributed to 50 selected daily and weekly newspapers, television and radio stations, wire services, and special correspondents. Comprehensive articles on the Laboratory were prepared for use in "special editions" of the Mississippi Press (March 1976) and the Sun-Herald (July 1976).

Numerous briefings on the Laboratory and guided tours of the facilities and research projects were provided to an average of one high school science class per week during the school year and to special groups such as junior high school principals, junior college students, and Laboratory summer students.

Gulf Research Reports, Volume 5, Number 1, was the first issue in the new 8 ½ x 11 inch page size and contained 62 pages, which included four technical papers and two short communications. Three of these were authored by Laboratory personnel. In December 1975, about 800 copies of the journal were mailed, including 270 to foreign countries. The *Reports* are exchanged for 102 foreign publications and 58 stateside publications.

Copy editing and manuscript setting for Volume 5, Number 2, began in December 1975. By the end of the fiscal year five technical papers and two short communications had been accepted for publication, set and proofed.

Gulf Research Reports titles are now listed in *Marine Science Contents Tables, Aquatic Sciences and Fisheries* and *Current Contents/Agriculture, Biology and Environmental Sciences.*

The Section also writes, edits, sets, proofs and lays out copy for the Laboratory newsletter, *Marine Briefs,* which is written in non-technical language; it was mailed each month to an average 3,280 recipients. Any organization or individual interested may receive this publication.

Two slide programs with printed and taped narrations were produced on different aspects of the seafood industry and are now available on request. The first program, entitled "The Canning of Shrimp in Mississippi" was made with the cooperation of Southern Shell Fish Company, Biloxi. The second program, entitled "The Packing of Raw Oysters by Mississippi Processors," was made with the cooperation of the E. M. Gollott Company, Biloxi. Copies of the programs have been donated to the Mississippi Museum of Natural Science, Jackson.

Production of a 15-minute taped radio program called "On Course," began in January 1976. It was accepted by five local stations and is being broadcast on a weekly basis. By the end of June, 23 programs had been aired and they involved 23 members of the Laboratory staff, faculty and students, plus 10 invited guests representing as many other state and federal agencies and political subdivisions.

ACADEMIC PROGRAM

SUMMER SESSION

During the 1975 summer academic session, 102 students registered individually for a total of 145 student courses. Formal courses offered during that session were:

Marine Botany
Salt Marsh Ecology
Marine Chemistry
Physical Marine Geology
Chemical Marine Geology
Introduction to Marine Zoology
Marine Invertebrate Zoology
Marine Vertebrate Zoology
Aquaculture
Marine Ecology
Marine Fisheries Management
Basic Techniques in Marine Science for Teachers
Special Problems in Marine Science

Forty-four students registered through Mississippi schools, 56 through out-of-state affiliates and 2 through nonaffiliated out-of-state institutions. The 1975 session showed a 5 percent increase in students over the 1974 session.

As an adjunct to the academic program, the Laboratory each year provides, at nominal costs, living accommodations, classroom laboratories, and essential services to visiting scientific field trip groups made up of college and university students and their professors. These groups may stay for periods of up to several weeks, live in the dormitories, use Laboratory boats to make collections of marine life from the sea and from the beaches of offshore islands, and study their specimens in the classroom laboratories. There were 44 visiting field trip groups in the past year. Some came as far as 2,000 miles to study marine life in the Gulf of Mexico.

AFFILIATED ACADEMIC INSTITUTIONS

IN-STATE

Alcorn State University, Lorman, MS
Belhaven College, Jackson, MS
Delta State University, Cleveland, MS*
Jackson State University, Jackson, MS*
Millsaps College, Jackson, MS
Mississippi College, Clinton, MS*
Mississippi State University, Mississippi State, MS*
Mississippi University for Women, Columbus, MS*
Mississippi Valley State University, Itta Bena, MS
University of Mississippi, University, MS*
University of Mississippi Medical Center, Jackson, MS*
University of Southern Mississippi, Hattiesburg, MS*
William Carey College, Hattiesburg, MS

OUT-OF-STATE

Auburn University, Auburn, AL*
Arkansas Tech University, Russellville, AR
Hendrix College, Conway, AR
Berry College, Mount Berry, GA
North Central College, Naperville, IL
Iowa State University, Ames, IA*
Wartburg College, Waverly, IA
Westmar College, LeMars, IA
St. Joseph's College, Rensselaer, IN
Louisiana State University, Baton Rouge, LA*
Louisiana State University Medical Center, New Orleans, LA*
McNeese State University, Lake Charles, LA*
Northeast Louisiana University, Monroe, LA*
Southeastern Louisiana University, Hammond, LA*
Central Methodist College, Fayette, MO
Northeast Missouri State University, Kirksville, MO*
Northwest Missouri State University, Maryville, MO*
Southeast Missouri State University, Cape Girardeau, MO*
Southwest Missouri State University, Springfield, MO*
Queens College, Charlotte, NC
Jamestown College, Jamestown, ND
Bowling Green State University, Bowling Green, OH*
Southwestern Oklahoma State University, Weatherford, OK*
Coker College, Hartsville, SC
Presbyterian College, Clinton, SC
Lambuth College, Jackson, TN
Memphis State University, Memphis, TN*
Southwestern at Memphis, Memphis, TN
Tennessee Technological University, Cookeville, TN*
Tennessee Westleyan College, Athens, TN
Union University, Jackson, TN
University of Tennessee at Martin, Martin, TN*
University of Tennessee at Nashville, Nashville, TN
Southern Methodist University, Dallas, TX*
University of Washington, Seattle, WA*

*INSTITUTIONS WITH GRADUATE PROGRAMS

New Affiliates: Louisiana State University Medical Center at New Orleans; the University of Tennessee at Martin; and the University of Washington at Seattle, became affiliated with the Laboratory during this fiscal year.

GRADUATE RESEARCH PROGRAM

During the year, five students were accepted into the Laboratory graduate research program, one student completed his degree and one student withdrew. At present there are in residence seven candidates for the master's degree and six candidates for the doctorate.

Each candidate's name, thesis title, degree sought and home university are listed below according to research sections directing their work:

Ecology Section: Jerry A. McLelland, "The summer vertical distribution of Chaetognatha in the northeastern Gulf of Mexico," M.S., University of Southern Mississippi.

John P. Steen, Jr., "Factors influencing the spacial and temporal distribution of selected crustacean plankton species in Davis Bayou," Ph.D., University of Mississippi.

Environmental Chemistry: Sharon H. Walker, "An environmental survey of fatty acids in the northeastern Gulf of Mexico," M.S., Louisiana State University.

Microbiology Section: John D. DeMond, "Amphipod fouling of an artificial reef in the north central Gulf of Mexico," M.S., University of Southern Mississippi.

Microscopy Section: Carolyn A. Foster, "Ultrastructure of the gill of the brown shrimp, *Penaeus aztecus* Ives in relation to salinity variations," M.S., University of Southern Mississippi.

Oyster Biology Section: David A. Blei, "A successional study of the hydrozoans inhabiting an artificial reef in the north central Gulf of Mexico," M.S., University of Southern Mississippi.

Neil Cave, "Predator-prey relationships involving the American oyster *Crassostrea virginica* Gmelin, and the black drum *Pogonias cromis* Linnaeus, in the Mississippi Sound," M.S., Southeastern Louisiana University.

Alfred P. Chestnut, "Substrate competition between *Crassostrea virginica* Gmelin and associated sessile marine invertebrates," Ph.D., University of Southern Mississippi.

Katherine A. McGraw, "A comparison of the growth and survival rates of hatchery reared and natural oyster spat at selected locations in Mississippi Sound and adjacent waters," Ph.D., University of Washington.

Parasitology Section: Daniel R. Brooks, "Systematic studies on the digenetic trematodes of crocodilians with emphasis on the family Acanthostomidae," Ph.D., University of Mississippi.

Richard W. Heard, "Microphallid trematode metacercariae in fiddler crabs of the genus *Uca* from Mississippi," Ph.D., University of Southern Mississippi.

Tom E. Mattis, "Larval development of two trypanorhynch cestodes from Mississippi Sound," Ph.D., University of Southern Mississippi.

Mobashir Ahmad Solangi, "Pathological changes in some estuarine fishes when challenged by crude oil fractions," Ph.D., University of Southern Mississippi.

SPECIAL AND COMMUNITY SERVICES

PUBLIC SEMINARS

The Gulf Coast Research Laboratory hosts a series of staff seminars throughout the year. These seminars are open to the public and speakers include invited scientists as well as officials from various levels of local, state and federal governments. The central purpose of the seminars is to promote better dissemination, understanding, and use of scientific information at all levels of society. Seminars presented during fiscal year 1976 were as follows:

"Marine Studies in the Ole Miss Pharmacognosy Department" by Dr. Norman J. Doorenbos, Department of Pharmacognosy, University of Mississippi, July 8, 1975.

"Oenology Research at Mississippi State University" by Dr. B. J. Stojanovic, Department of Horticulture, Mississippi State University, August 5, 1975.

"There is More Wealth in an Acre of Sea than in an Acre of Land" by Mr. Edward A. Khayat, President, Jackson County Board of Supervisors, September 9, 1975.

"Requirements for a Fishery Management Program in Mississippi's Marine Fisheries" by Mr. Charles H. Lyles, Director, Mississippi Marine Conservation Commission, October 7, 1975.

"Mississippi Sandhill Crane–Surrender or Survival" by Dr. Robert E. Noble, Department of Forestry and Wildlife Management, Louisiana State University, November 4, 1975.

"Fate of Nitriloacetic Acid (NTA) in Estuarine Waters" by Dr. Al W. Bourquin, U.S. Environmental Protection Agency, Gulf Breeze Environmental Research Laboratory, December 9, 1975.

"Cultural Resource Studies–Continental Shelf–Northern Gulf of Mexico" by Dr. Sherwood Gagliano, Coastal Environments, Inc., January 27, 1976.

"Tornadoes" by Dr. Robert G. Watts, Department of Mechanical Engineering, Tulane University, February 24, 1976.

"The Mississippi Sound's First Seed Oyster Hatchery" by Dr. Edwin W. Cake, Jr., Head, Oyster Biology Section, Gulf Coast Research Laboratory, March 9, 1976.

"Relationship of Law to the Marine Scientist" by Mr. Joel Blass, Attorney, Legal Counselor, Gulf Coast Research Laboratory, March 16, 1976.

"Overview and Future Plans of the Mississippi Park Commission" by Dr. James Meredith, Director, Mississippi Park Commission, April 20, 1976.

"Evolution–What do the Experts Say?" by Mr. Robert Allen, Microscopy Section, Gulf Coast Research Laboratory, May 18, 1976.

SYMPOSIUM ON COASTAL ZONE

The Gulf Coast Research Laboratory convened and sponsored, along with the Mississippi Academy of Sciences, Mississippi-Alabama Sea Grant Consortium, Mississippi Marine Resources Council and the Mississippi Marine Conservation Commission, a Symposium on the Mississippi Coastal Zone Environment in conjunction with the Annual Meeting of the Mississippi Academy of Sciences on March 4, 1976.

The purpose of the symposium was to tell the general public as well as interested scientists about work being done on the management of coastal zone resources, ascertain new problems and possible solutions, and discuss future needs in research and management.

Speakers who took part in the symposium and the titles of their papers are listed below:

"Geological evolution and recent geology of the Mississippi-Alabama Gulf coast" by Dr. Ervin Otvos, Section of Geology, Gulf Coast Research Laboratory.

"An overview of Mississippi Sound hydrography: changes, forces, interactions and implications" by Mr. Charles K. Eleuterius, Section of Physical Oceanography, Gulf Coast Research Laboratory.

"Hydrocarbons in the northeastern Gulf of Mexico" by Drs. Julia and Tom Lytle, Section of Environmental Chemistry, Section of Analytical Chemistry, Gulf Coast Research Laboratory.

"Pesticide levels in the Mississippi coastal zone" by Dr. William W. Walker, Section of Microbiology, Gulf Coast Research Laboratory.

"Distribution of fecal pollution indicator bacteria in waters of the Mississippi Sound" by Dr. David W. Cook, Section of Microbiology, Gulf Coast Research Laboratory.

"Evaluating the value of marshlands" by Dr. Armando A. de la Cruz, Department of Zoology, Mississippi State University.

"The seasonal periodicity of seagrasses and seaweeds in Mississippi waters and their contribution to the marine environment" by Dr. Lionel N. Eleuterius, Section of Botany, Gulf Coast Research Laboratory.

"Food chains in the Mississippi coastal zone" by Dr. Robert A. Woodmansee, Section of Ecology, Gulf Coast Research Laboratory.

"Salt water angling in Mississippi" by Mr. Thomas D. McIlwain, Section of Anadromous Fishes, Gulf Coast Research Laboratory.

"Coastal zone management and marine resources" by Mr. J. E. Thomas, Director, Mississippi Marine Resources Council.

The symposium was co-chaired by Dr. H. D. Howse, Director, and Dr. G. Gunter, Director Emeritus, Gulf Coast Research Laboratory.

These papers will appear in the Journal of the Mississippi Academy of Sciences, Volume XXI, scheduled for publication in the fall of 1976.

SYMPOSIUM ON MISSISSIPPI FISHERIES

In April, Gulf Coast Research Laboratory conducted a one-day symposium on Mississippi fisheries for selected personnel of the Mississippi Research and Development Center.

Members of the Gulf Coast Research Laboratory staff briefed the R&D Center personnel on conditions within the shrimp, bait shrimp, blue crab, oyster, and both commercial and sport finfish fisheries.

Representatives of seafood processors, raw stock seafood wholesale and retail businesses and Sea Grant Advisory Services also participated in the symposium.

STAFF PUBLICATIONS

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